Dr. C. Srinivasan

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PREFACE

Studies in the morphology, anatomy, physiology and ecology of 64 different species of South Indian Mosses have been made. The contribution recorded herein have been made for the first time.

Systematic description of 64 species of more common South Indian Mo ses has been attempted in detail. Critical study reveals that the structure of the leaves appears to be well-adapted for the retention of water. The foot of the sporophyte has been found to be of 8 different forms. The L/B (Length/Breadth) ratio of the stomata observed on the apophysis of 8 pecies appears to be a constant feature. The stomatal index has been found to be specific.

The transverse sections of the axes of most of the species (53) have been described in a systematic manner. On a close study of the internal structure of the moss axes, it has been possible to classify th m. The proposed system of classification though based purely on anatomical peculiarities of the gametophyte is in conformity with the prevailing systems of classification, in some respects.

The sporophytes of 10 species of mosses have been induced to produce rhizoids from the base of their foot by treatment with hormones and gametophytic-extract just to show that the moss sporophytes under proper cultural conditions could lead an independent existence for a short period. Secondly the osmotic concentration of the cell-sap of the cells of the sporophytes of

7 species has been found to be always higher than that of the gametophytes. Vegetative reproduction and regeneration in 11 species have been studied and recorded.

Ecological studies in the physiographic, edaphic and biotic factors in respect of the South Indian mosses and their formations and associations and relative frequency of some of the species have been made.

It is in these and in other details that the present investigations seek to be an attempt towards advancement of knowledge in Bryology.



FRONTISPIECE : ASSOCIATION OF *PAPILLARIA CROCEA*, *FLORIBUNDARIA FLORIBUNDA* AND *METEORIOPSIS RECLINATA* FORMING FESTOONS

Introduction

The study of the South Indian mosses was undertaken on the kind suggestion of Professor T.C.N. Singh, Head of the Department of Botany of the Department of Botany of the Annamalai University. While he had been working on the vegetative reproduction in certain mosses (Singh, 1930) under the guidance of Professor Birbal Sahni, F.R.S. of the Lucknow University, it transpires that the learned Professor had expressed a desire that this long neglected field of Botany, specially Indian mosses, should be carefully studied. Perhaps, it is almost the posthumous desire of that great Professsor that has fructified in a very small measure in the wake of the present investigation. The present study is based on 64 species, comprising of 55 genera spread over 24 families.

In the first instance I was introduced to the census of Indian mosses published by Brühl in 1931*. He has rightly pointed out the limitations of an Indian teacher of the plains for a work of this kind in the study and collection of mosses which grow in the mountainous regions.

The presnt work is obviously an attempt: (i) to describe the more common mosses of this part of the

* In 1930, Professor T.C.N. Singh had placed his entire large collection of Mosses of Simla Hills (North-Western Himalayas) at the disposal of Dr. P. Brühl.

country in detail; (2) to relate as far as possible their ecological peculiarities and their physiological behaviour; and (3) to submit a thought for the classification of the mosses on the basis of anatomical details

There is hardly any detailed work on the South Indian mosses. The earliest reference on these plants is by Brotherus (1899). He, in his report on a collection of mosses made by Walker in Coorg during the cold weather of 1897-1898, says that "the Bryological Flora of South India is very little known." He has enlisted 98 species of mosses of which 20 were described as new species. Cardot (1911), according to Foreau (1930), estimated the moss flora of the Palni Hills to consist of 191 species of which more than 50, he considered, were new to science. Dixon (1914) in his report on the mosses collected by Fischer from South India, has enumerated 58 species of which 6 were described as new species Of these mosses 11 species find a place in the present investigation. Dixon (1923) has also enlisted 43 species of mosses collected in 1921 from the Kanara district of South India by Sedgewick and also of those received from Mons. Cardot. He has stated that he had in his herbarium, "numerous unpublished species of mosses from various parts of India including the types of a considerable number of new species mostly from the Madura district of South India." It is these mosses that form the bulk of the present treatise. Only 3 species out of his report are described in the present work. Subsequently Potier de la Varde (1922), (1925), (1928 a), (1928 b); Cardot and Varde (1922); Dixon and Varde (1927, 1928) have listed the South Indian mosses and

described some new species. It is interesting to note that Dixon and Varde (1927), (1928) have erected 2 new genera of mosses from this part of India, represented by *Trigonodyction indicum* Dix. et Vard. and *Foreauella indica* Dix. et Vard.* Foreau (1930) has published an interesting and very useful note on the Bryological Geography of the Palni Hills and enumerated the mosses found there. Brühl (1931) in his census of Indian Mosses brought out a very comprehensive list of mosses occurring not only in India but also in Ceylon and Malaya Peninsula. His analytical key to the genera and their description were of some help in identification. Sedgewick (1947-1950) published a list of mosses of the Bombay presidency into which region I have not extended this study. Very recently Foreau (1961) has published a list of 368 species of moss flora of the Palni Hills with the exact places and dates of collection along with the Greek and Latin derivations of the generic names of the mosses.

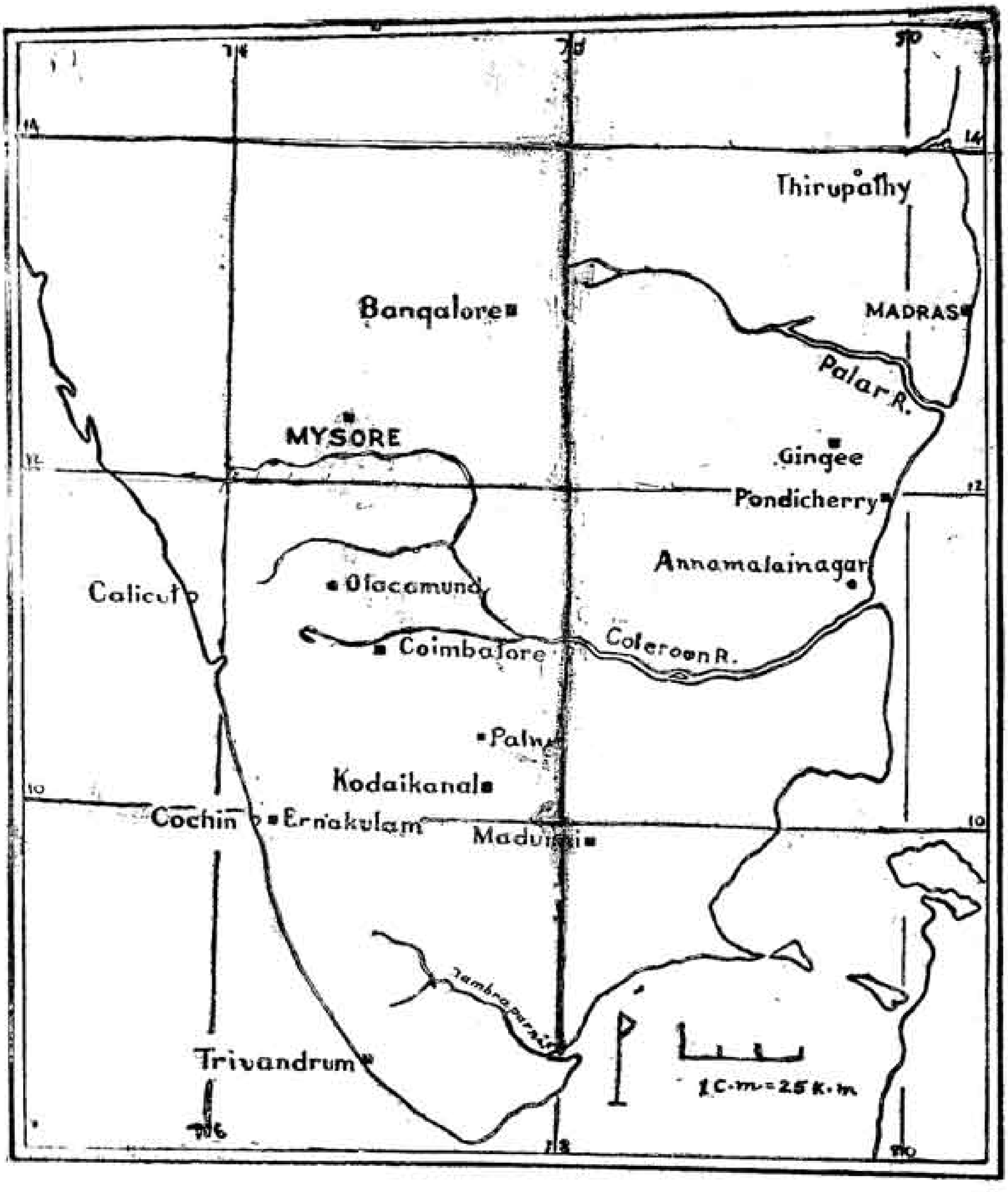
There is, therefore, hardly any work on the South Indian mosses and the observations presented in this communication comprise of details being recorded for the first time.

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* This genus has been named after Rev. Fr. G. Foreau who has been a very painstaking muscologist who in spite of his old age not only showed me the natural home of the mosses but also helped me greatly in collecting them during my periodical excursions to the Kodaikanal Hills.

Materials And Methods

About 100 different species of mosses were collected from the hills of Palni, Ginjee, Yercaud and Tirupati and from the mountainous regions of Kodaikanal (Madura district) and Ootacamund (Nilgiri district). A few were obtained from the hills in Trivandrum and Mysore. Out of these, only 64 species spread over 55 genera have been inc'uded in the persent study. The collection was made in different seasons such as wintry days of November and December and the summer days of April and May. Some mosses were collected during September and October also when they were observed with their capsules. The plants were preserved dry in small paper packets. Herbaria of these plants were prepared for facilitating identification. Fer detailed study, the leaves were carefully removed under the stereo-microscope and mounted in a special medium consisting of 90 c.c. of 30% glycerine, 2 c.c. of 1% aqueous safranin and 8 c.c. of F. A. A. (5 : 5 : 90 of 50%). This mixture keeps the material not only well spread and stained suitably but also free from the attack of insects and fungus. Similarly, entire plants with the capsule wherever available, were mounted. The ripe capsule was ripped open and the peristome with the capsular wall, the entire apophysis region, the spores and the rhizoids were all mounted in a similar manner.



MAP OF SOUTH INDIA

The foot of the seta was carefully removed from the apex of the gametophore with a pair of very fine needles in living condition and mounted thereafter.

The usual process of fixing in F. A. A. and dehydration in chloroform and sectioning with rotary microtome was adopted for the sections of the axes and leaves. They were cut to thickness of 10μ to 12μ. Double embedding in celloidin and later in paraffin was also done specially for sectioning longitudinally the foot of the seta while still attached to the gametophore. Considerable amount of difficulties were experienced in the matter of infiltration and microtomy. The leaves shrink in absolute alcohol and the microtome sections when they become dry, shrivel and roll upwards from the paraffin wax and fall off during the processes of staining. But this difficulty could be obviated by cutting out the material towards one end with a fine sharp blade and thus exposing it while still in the block and then dipping the block either in water or in 50% glycerine for a considerable time and thus softening the material. Double staining in safranin and fast green gave contrasting differentiation. Free hand sections stained suitably and mounted in the glycerine mixture mentioned above were largely used. Staining in phlo - roglucin, methylene blue were also tried. The axes of some of the mosses were treated with Schultze's maceration fluid and the cells were subjected to micro-chemical tests.

Certain growth hormones such as I. B. A.; I. A. A.; I. N. A.; and 2, 4-D were used in different concentrations of .5 p. p. m. to 20 p. p. m. in order to see whether the sporophytes and leaves (gametophyte) produce rhizoids.

These experiments were conducted at both the hill stations of Kodaikanal and at Ootacamund in two different seasons (October and April). The same growth hormones excepting I. N. A. were applied to the local moss (*Barbula indica)* which grows very luxuriantly during winter in the plains and also on the terrace of the laboratory. For these mosses buffer solutions of different pH namely 4 to 9 were sprayed in their natural habitat to find out whether these substances promote or affect the growth of the mosses.

Osmotic concentrations with in the gametophyte in the young leaves and transverse sections of axis and those of the sporophyte in the wall cells of the apophysis region of the capsule and also of the seta were determined for some of the mosses by the de Vries' plasmolytic method using the solutions of Sodium chloride, Potassium nitrate and Dextrose in different concentrations. The pH of the peaty soil formed by the local moss, *Barbula indica*, on the terrace of buildings and the soil of some of the soil mosses were determined with thehelp of La Motte Morgan Soil Testing set. The nitrogen content of a rock moss was examined in our Bio-chemical Section of the department. The results are given in the chapter on physiological observations.

Some of the results of these investigations have, from time to time been contributed as abstracts, being read in the Botany Section of the Indian Science Congress Association (Srinivasan, 1958, 1960a, 1960b, 1961).

The mosses without sporophytes (described in the chapter on morphological observations) are indicated with asterisks. All the diagrams and photographs have

been numbered in a serial manner. The photographs of the mosses studied, have been arranged in plates (Figs. 477–535). A few species of mosses were also photographed in their natural habitat and included (Frontispiece and Figs. 538–549). Photomicrographs in support of some of the diagrams have been appended (Figs. 550-584). The diagrams have been drawn with Zeiss Winkel camera lucida using Zeiss Winkel Research Microscope. The magnifications are noted against each. Wherever the laminar cells are enlarged, exact region of the leaf is pointed out with an arrow. Whenever the cells are different in size and shape in one and the same leaf and when they are enlarged as separate diagrams, those different regions of the leaf, are indicated by means of arrows and marked 'a' and 'b'.

Morphological Observavions

Fissidentaceae

1. *Fissidens schimidii* C. M.: Plants grow in small tufts on clayey ground in the moist woods of Shembaganur (Kodaikanal) at an altitude of 2000 metres or on wet soil-covered-rocks in shaded regions of Trivandrum 300 metres forming thin mats, bright to dark green. Soil acidic, pH being 5.4 to 5.6 Plants (Figs. 1 & 2): very small slender, 8 mm to 10 mm high. Leaves: bifarious, stem-clasping; .88 mm to 1.21 mm long and .09mm to 13mm broad, dorsal lamella strongly developed; apex acute; leaf-cells (Fig.4) rectangular to hexagonal, 8 cells in a square of 22μ; margin bordered by one row of elongated rectangular cells; mid-rib thin. Sporophyte: terminal or lateral; seta 8 mm to 10 mm long; Sporocapsule sub-erect to inclined, .9 mm to 1.2 mm long and .3 mm to .4 mm broad; peristome (Fig. 6) deeply bipartite 264μ long and 22μ broad at base operculum (Fig. 357) long beaked; spores (Fig. 386) spherical 11μ to 13μ in diameter.

Ditrichaceae

2. *Ditrichum amoenum* (Thw. and Mitt.) Par.: Plants grow crowded on moist clayey soil on road-side near Observatory (Kodaikanal) 2300 metres: or in shaded cave sides at Fernhill (Ootacamund) 2300 metres. Soil

acidic, pH being 5.2 to 5.4. Plants (Figs. 7 & 8): bright yellowish green, fruiting abundantly; stem erect and short 10 mm to 15 mm with capsule; gametophyte 3 mm to 5 mm; leaves (Fig. 9) hairy 3.8 mm to 6 mm long and .3 mm to .4 mm broad at base; apex attenuate; leaf-cells (Fig. 10) elongated rectangular, 3 cells in a square of 22. Capsules (Fig. 11) 2 mm to 2.3 mm long and .4 mm to 5 mm in diameter; operculum (Fig. 358) 17μ to 190μ long; peristomial teeth (Fig. 12) slender thread like 232μ long with minute marginal papillae; spores (Fig. 387) spherical, 15μ to 17μ in diameter.

3. *Trematodon ceylonensis* C. M.: Plants grow in swampy regions of Perumal hill shola (Kodaikanal) 1600 metres: plants (Fig. 13&14): 20 mm to 30 mm in height with the sporophyte, greenish yellow and shiny. Leaves (Fig. 15): 2.5 mm to 4 mm long and .4 mm to .5 mm broad at base, lanceolate subulate; apex revolute; margin slightly serrulate; leaf-cells (Fig. 16) rectangular, cells of the costa narrowly rectangular. Sporophyte: 20 mm to 25 mm long; seta erect yellowish and shiny; capsule (Fig. 17) 7 mm to 9 mm × .5 mm to .7 mm with much longer neck; operculum (Fig. 359) and calyptra hooded peristome teeth (Fig. 19) entire; apophysis provided with stomata (Fig 18) resembling those of dicots but with numerous subsidiary cells varying from 7 to 8; spores (Fig. 388) spherical, 22μ to 24μ in diameter.

Dicranaceae

4. *Campylopus nodiflorus* (C. M.) Jaeg.: Plants grow on the bark of tree trunks in thick forests

of Silvercaskade (Kodaikanal) 2200 metres, Thoddabedda (Ootacamund) 2800 metres. Plants (Fig 20) 40 mm to 45 mm tall Leaves 3 mm to 5 mm long .3 mm to .4 mm broad at base (Fig. 21), ovate and attenuated into straight long tip; apex (Fig. 22) with serrated margin; leaf-cells (Fig. 23) 50μ to 55μ × 20μ to 22μ, elongated; alar cells (Fig 24) rectangular, marginal cells narrow and elongated. Seta unusually short and bent variously 8 mm to 10 mm long; capsule (Fig. 25) 1.4 mm to 1.75 mm long and .8 mm to 1 mm broad, spherical and drooping with long beaked operculum (Fig. 360); peristome (Fig. 27) teeth bipartite, hair-like, united at base, annulus (Fig. 26) specialised ring of vesicular cells flask-shaped; spores (Fig 389) 15μ to 17μ in diameter.

5. *Thysanomitrium depallieri* Card. * : Plants grow on flat rocky, water-oozing substratum, in bright sun shine in the Priests'Walk (Kodaikanal, 2000 metres. Plants (Fig. 33) dark green, gametophytes 9 cm to 12 cm long. Leaves (Fig. 34): 6 mm to 9 mm long, 1.5 mm to 2 mm broad, slightly concave passing into a lanceolate upper part ending in a hair point; apex (Fig. 30) with fimbriate margin; leaf-cells (Fig. 32) almost rectangular 33μ to 35μ × 16μ to 18μ ; marginal and mid-rib cells narrower; alar cells quadratic (Fig. 31). Profuse unbranched rhizoids (Fig. 34) found at the base of leaves.

6. *Thysanomtirium lioneurum* (Ther. and Vard.) Broth. :* Plants grow in dense patches on ground or rock near Thoddabedda (Ootacamund) 2600 metres and on waysides of Tigershola (Kodaikanal) 2100 metres.

Plants (Fig. 28) 4 cm to 4.5 cm tall. Leaves (Fig. 29): 3 mm to 5 mm long and .5 mm to .75 mm broad at base, oblong passing into a lanceolate upper part ending in a blunt point (Fig. 35); leaf-cells (Fig. 36) elongated rhomboid; cell-walls thickened; alar cells differentiated; marginal cells thin in three rows; mid rib broad, cells typically rectangular and thinner.

7. *Brothera leana* (Sull.) C. m. * : Plants grow closely on rotting tree trunks at Perumal hill road (Kodaikanal) 1675 metres, 7 mm to 10 mm tall (Fig. 38). Leaves (Fig. 39): lanceolate 3 mm to 5 mm long and .25 mm to .4 mm broad at base; margin entire; apex (Fig. 40) pointed, leaf cells (Fig. 41) hyaline, rectangular.

8. *Dicranodontium fragile* (Hook.) Broth. : Plants grow on shaded rocks and on decaying wood in the woods of Priests' Walk (Kodaikanal) 1700 metres in dark green tufts and small patches, 4 cm to 4.5 cm tall (Fig. 42). Leaves (Fig. 43) form a broad concave base, linear oblong 1 mm to 3 mm long and .6 mm to .8 mm broad at base; costa in narrow seam; cells of the lamina (Fig. 45) rectangular in linear stereids; cell wall thickened; alar cells broad rectangular, differentiated, forming 6 to 7 rows; apex (Fig. 44) prolonged with serrated margin. Seta at first decurved, finally erect 10 mm to 12 mm long; capsule (Fig. 46) 5 mm to 6 mm × .8 mm to 1 mm, cylindric; operculum (Fig. 361) long beaked; peristome (Fig. 47) teeth 16 each with 9 to 10 basal partitions and bipartite above; spores (Fig. 39) spherical, 25μ to 27μ in diameter.

Leucobryaceae

9. *Leucobryum neilgherrense* C. M. : Plants grow in small pale green clusters on tree trunks, rocks and shady ground in various parts of South India; Jingee hills (South Arcot) 250 metres, Old Ghat Road, (Kodaikanal) 1870 metres, Simp's Park (Ootacamund) 2500 metres. Soil acidic, pH being 5.6 to 5.8 plants (Fig. 48) 15 mm. to 18 mm. tall, green. Leaves (Figs 48 & 49) thick, narrow linear 3.5 mm to 5 mm long .5 mm to .75 mm broad. whitish when dry ; costa differentiated ; apex (Fig. 50) acute ; laminar cells (Fig. 52) slightly elongated rectangular, chloroplasts light and pale green. Rhizoids found to arise from the basal, marginal and apical cells of the leaf also. Sporophyte terminal ; seta short 4 mm to 5 mm long ; capsule (Fig. 53) erect or inclined slightly, sub-ellipsoid 2.5 mm to 4 mm × .7 mm to .9 mm ; lid conical (Fig. 362); peristome teeth (Fig. 54) subulately bifid ; spores (Fig. 390) spherical 18μ to 20μ in diameter.

10. *Leucobryum scalare* C.M. : Plants grow in light green tufts on tree trunks in the forest of the Priests' Walk (Kodaikanal) 1700 metres and in the Sim's Park (Ootacamund) 2000 metres. Gametophytes (Fig. 55) 3 cm to 4 cm tall, branching from base in clusters of 4 to 6 fastigiate. Leaves (Fig. 56) thick, long and narrow 3.5 mm to 5 mm long and 1.5 mm to 2 mm broad ; apex (Fig. 57) acute with serrulate margin ; laminar cells (Fig. 59) rectangular 44μ × 30 costa not differentiated ; marginal cells thin elongated.

11. *Tortula muralis Hedw.*: Plants grow on rocks and road sides near the wood house (Ootacamund) 2750 metres in small dark green cushions about 1 cm. tall (Figs. 60 & 61). Leaves (Fig. 62) 2.5 mm to 3.5 mm long and .4 mm to .5 mm broad, keeled and ligulate; margins incurved; costa (Fig. 63) terete, prolonged beyond the leaf blade as a hyaline hair 440μ to 450μ long; leaf-cells (Fig. 64) rectangular, upper leaf cells smaller, cells of the costa narrow and long. Seta purple and erect 11 mm to 13 mm long; capsule cylindric (Fig. 65) 4 mm to 4.2 mm $\times$ .5 mm to .6 mm; operculum (Fig. 363) long conical about 2 mm long beyond the capsule head; peristome (Fig 67) with 32 filiform long twisted teeth (Fig 112); spores (Fig. 394) spherical, sparcely granulose 9μ to 10μ in diameter.

12 *Barbula indica* (Schw.) Brid: Common in acidic soil, the pH being 6.2 to 6.4; cosmopolitan in distribution in the plains and in the hills; growing gregariously on old brick-walls, terrace of buildings and on moist rocks. Hill plants grow taller but usually do not fruit. Plants (Figs. 68&69) yellowish green 1 cm to 2 cm tall; rhizoids branched with oblique cross walls. Leaves (Fig. 70): spirally alternate, oblong .8 mm to 1.5 mm long and .5 mm to .75mm broad; apex (Fig. 71) blunt; laminar cells (Fig. 72) rectangular; cells of costa narrower. Sometimes club-shaped gemmae (Fig. 73) produced in clusters in the axils of upper leaves; obovate multicellular with a basal cell, 30μ to 50μ long and 14μ to 18μ. broad. Sporophyte terminal or lateral; seta erect 5 mm to 7 mm long; capsule

(Fig 74) ovoid 2 mm × .15 mm ; peristome (Fig. 77&78) filiform with fimbriate margin; operculum (Fig. 364) conical; stomata present on apophysis, guard cells two (Fig. 75) sometimes the guard cells of the stomata in the lower regions near the seta divided by cross striations (Fig. 76); spores (Fig. 393) greenish, spherical, 15μ to 16μ in diameter.

13. *Trichostomum cylindricum* (Bruch.) C. M. : Plants bright green, grow on ground and on moist rocks of Shenbaganur (Kodaikanal) 1800 metres; 20 mm to 25 mm tall (Figs. 79 & 80). Leaves (Fig. 81) 3 mm to 4 mm long and .7 mm to .8 mm broad at base, keeled ventrally concave, lanceolate, upper portion secund; apex (Fig. 82) sharply acute; alar cells (Fig. 84) elongated rectangular to quadratic 44μ long and 29μ broad, upper cells 5μ to $6\mu \times 2\mu$ to 3μ only, cells towards the mid-rib still smaller, cells of costa narrow and elongated rectangular. Seta 8 mm to 10 mm long; capsule (Fig. 84) slightly inclined, cylindric, 2.5 mm to 3 mm × .5 mm to .7 mm operculum (Fig 365) conical ; peristome teeth (Fig. 85) entire; spores (Fig. 393) spherical, brownish, thinly granulose 15μ to 16μ in diameter.

14. *Weisia macrospora* Card. : Plants grow in mats on soil and in cracks of rocks in Pillar Rocks (Kodaikanal) 2000 metres, 10 mm to 15 mm tall (Figs. 86&87). Upper leaves (Fig. 88) usually larger than the lower, erect, spreading, much elongated, lanceolate; apex (Fig. 89) prolonged, acute; mid-rib well developed, lamina folded or canaliculate; leaf-cells (Fig. 90) ovate, cells of costa narrowly elongated. Seta erect, moderately long 8 mm

to 10 mm; capsule (Fig. 91) ovoid to ellipsoidal .5 mm to .75 mm × .5mm; operculum (Fig. 366) long beaked; peristome (Fig. 92) inner teeth short in two rows, outer peristome not developed; spores (Fig. 406) spherical, 12μ to 14μ in diameter.

15. *Hyophila involuta* (Hook.) Jaeg. : Plants grow on walls, and on wet rocks in Perumal hills 2000 metres Shenbaganur (Kodaikanal); short 2 cm to 2.5 cm tall (Figs. 92 & 93). Axial column scarcely differentiated. Leaves (Fig. 94) oblong, 2 mm to 3 mm long and .5 mm to .7 mm broad; apex (Fig. 97) acute with serrate margin; leaf-cells (Fig. 98) 8 to 9 in a square of 22μ, hexagonal near mid-rib, rectangular towards margin; margin differentiated by one row of ovate cells, cells of costa thin and elongated rectangular. Seta brownish 10 mm to 12 mm long; capsule (Fig. 95) cylindric, 2.7 mm to 3 mm × .5 mm to .6 mm; lid (Fig. 367) conical; annulus (Fig 96) in two rows; spores (Fig. 403) roundish, 9μ to 10μ in diameter.

16. *Hyophila validinervis* Card. and Vard.*. Plants grow in small tufts on soil and on rock in Priests' Walk (Kodaikanal) 2400 metres; 1.5 cm to 2 cm tall (Figs. 99 & 100). Leaves (Fig. 101) oblong; apex (Fig. 102) obtuse; laminar cells (Fig. 103) rectangular to quadratic towards the midrib, those towards the margin hexagonal; margin not much differentiated, cells quadrate; mid-rib prominent, cells linear. Branched rhizoids produced at the base of the leaves too.

Grimmiaceae

17. *Rhacomitrium javanicum* Bryol.* : Plants grow with creeping axis in rigid tufts on moist rocks of Priests' Walk (Kodaikanal) 1900 metres. Plants (Fig. 104) dark green, 5 cm to 8 cm tall. Leaves (Fig. 105) 2 mm to 2.2 mm long and .7 mm to .9 mm broad at base lanceolate; apex bluntly acute, leaf-cells (Fig. 106) long and narrow, alar cells with much thickened cell-wall, wavy longitudinal and thinner, transverse thickening characteristic; the margins usually recurved; costa prominent and broad.

Funariaceae

18. *Funaria hygrometrica* Hedw.: Plants grow close together in small patches on ground in the woods of Tiger hill 2800 metres and in the open swampy soil at Kern hill (Ootacamund) 2300 metres. "Its presence marks the site of a recent fire". Plants pale green, gametophytes 1 cm to 2 cm tall but with sporophyte 3 cm to even 8 cm tall (Fig. 108). Leaves (Fig. 109) spathulate 2 mm to 2.2 mm long and 1 mm to 1.5 mm broad; margins often incurved and slightly wavy; leaf-cells (Fig. 110) large almost hexagonal. Sporophyte terminal: seta long greenish yellow when young, reddish brown later, curved and twisted 45 mm long; capsule (Fig. 111) pear shaped, held horizontally 3.5 mm to 4 mm × .8 mm to 1.5 mm furrowed when dry, mouth oblique bearing inner and outer peristome (Figs. 111 & 113), the latter curved and united by their 16 fimbriate tips (Fig. 114) to a minute central disc; operculum convex with its characteristic spirally

arranged cells (Fig. 368); calyptra covering the capsule hooded at base, long and pointed above; spores spherical, thick-walled, brownish (Fig. 395) 9μ to 10μ in diameter.

19. *Funaria submarginata* Card. and Vard. : Plants grow in clayey soil 1 cm to 1.5 cm tall; (Figs. 115 & 116) in loose clusters on way side at Tiger hill (Ootacamund) 2700 metres. Leaves (Fig. 117) ovate elliptic, 1 8 mm to 2 mm long and .8 mm to 1.1 mm broad; apex acute; laminar cells rectangular to pentagonal; (Fig. 118) cells of costa thin and elongated, narrow cells constituting the margin. Sporophyte tirminal; seta 12 mm to 14 mm long brownish and erect; capsule ovate, (Fig. 119); 1.2 mm to 1.5 mm × .8 mm to 1 mm; operculum (Fig 369) slightly convex and round; peristome wanting; stomata (Fig. 121) on the wall of the apophysis; spores (Fig. 396) large spherical, granulose, 25μ to 27μ in diameter.

Bryaceae

20. *Pohlia flexuosa* (Mitt.) Broth : Plants grow in carpets on rocks in moist and shady places of Shempaganur (Kodaikanal) 1800 metres, (Figs. 122 & 123); 2.5 cm to 3 cm tall. Leaves (Fig. 124) lanceolate 2 mm long and .3 mm to .4 mm broad; apex (Fig. 125) attenuated with marginal serration and prolonged up to a fine point; leaf-cells (Fig. 126) elongated, 99μ to 111μ Sporophyte terminal; seta inclined reddish 15 mm to 17 mm. long; capsule (Fig. 134) ovate 7 mm to 7.1 mm × .9 mm to 1 mm; operculum (Fig. 370) convex ending in a sharp point; inner peristome 60μ, with outer peristome

also (Fig. 127); spores (Fig. 397) spherical, 15μ to 17 in diameter.

21. *Brachymenium exile* (Doz. and Molk.) Bryol.: Plants dirty green; grow on soil on way sides to Perumal hill (Kodaikanal) 1600 metres or at Gudalur 2300 metres, or on the way to Thoddabedda (Ootacamund) 2800 metres. Soil acidic, pH being 6.2 to 6.4. Plants form loose tufts, 2 cm to 3 cm tall (Figs. 128 & 129). Leaves ovate (Fig. 130) 5 mm to .6 mm long and .15 mm to .17 mm broad; apex prolonged into a hair point, costa excurrent; laminar cells (Fig. 131) hexagonal, basal cells rectangular. Sporophyte lateral or terminal: seta 12 mm to 14 mm long and erect; capsule 2 mm to 2.1 mm × .17 mm; operculum (Fig. 371) cupola shaped and apiculate peristome (Fig. 132) hyaline; spores (Fig. 398) spherical, small 12μ to 14μ in diameter, thinly granulose. Multicellular hooked gemmae (Fig. 418) were found in the axils of leaves.

22. *Brachymenium leptostomoides* (C. M.) Shimp.*: Plants grow on tree trunks in the moist shaded forest of Priests' walk (Kodaikanal) 2250 metres. The gametophytes brownish green, .5 cm to 1 cm tall (Fig. 133 & 134). Leaves (Fig. 135). 6 mm to .7 mm long and .3 mm to .4 mm broad, oblong and spatulate with a marginal rim, costa strong and excurrent; apex (Fig. 136) prolonged and acuminate; laminar cells (Fig. 137) irregularly rhomboid 33μ to 11μ, marginal cells elongated and ovoid.

23 *Anomobryum subniditum* Card. and Vard.: Plants grow in the clefts of wet rocks and on the soil near

Pillar rocks (Kodaikanal) 2000 metres or at Golf-ground shola (Ootacamund) 2600 metres. Plants yellowish green 3 mm to 4 mm tall (Figs. 138 & 139). Leaves (Fig. 140) julaceous on the stem, oblong elliptic .5 mm to .6 mm long and .4 mm to .5 mm broad; mid-rib strongly developed, apex acuminate; leaf-cells elongated rhomboid and narrow (Fig. 142). Sporophyte lateral or terminal: seta red, 15 mm to 17 mm long and inclined; capsule ovate and elliptic 2.5 mm to 2.75 mm × 1 mm to 1.1 mm.; operculum (Fig. 372) apiculate slightly beaked; peristome teeth (Fig. 141) distinctly red with filiform upper portion; spores (Fig. 399) granulose, 15μ to 17μ in diameter.

24, *Bryum argenteum* Brid: These silvery mosses grow in small patches between bricks of walls or on culverts at Ootacamund and Kodaikanal 2000 to 2800 metres. Plants 2 cm to 3 cm tall cosmopolitan (Figs. 143 & 114). Leaves (Fig. 145) silvery grey in appearance due to lack of chloroplasts in the upper half, slightly concave, ovate, crowded and closely overlapping making the stem prettily julaceous; apex prolonged and bristle-like; leaf-cells (Fig. 146) quadratic to irregulary rhomboid. Sporophyte terminal or lateral. Seta red, inclined above, 12 mm to 14 mm long; capsule pendulous drooping, pear-shaped 3 mm to 3.1 mm. × 1.2 mm to 1.3 mm., when matured dark red, obovoid or sub-cylindrical, neck distinct; apophysis provided with stomata; operculum apiculate with blunt end (Fig. 373); peristome (Fig. 147) prominent 220μ to 240μ; inner peristome slender and numerous; spores (Fig. 400) spherical with thick coat 12μ to 14μ in diameter, sparsely granu ose.

25. *Rhodobryum giganteum* (Hook.) Par. : Plants grow in moist shady forests of Silver Cascade (Kodaikanal) 1700 metres or in Kern hill Reserve Forest Ootacamund) 2500 metres, with a creeping stem on the soil and rosette of broad and spreading leaves above (Fig. 148); 4 cm to 7 cm tall Leaves (Fig. 149) obovate 8 mm to 12 mm long and 4.5 mm to 5 mm broad, upper margin serrulate; apex (Fig. 150) acute with a hair-like projection; leaf-cells (Fig. 152) much elongated rhomboid with thickened walls, 88μ to 22μ, costa well developed excurrent. Sporophyte terminal: seta long erect 50 mm to 55 mm long; capsule (Fig. 151) cylindric, horizontal to pendent 8 mm to 9 mm × 1.6 mm to 1.75 mm; operculum (Fig. 374) umbilicate, cupola shaped; peristome with many narrow partitions free and close (Fig. 153); spores spherical (Fig. 401) 12μ to 14μ in diameter.

Mniaceae

26. *Mnium coriaceum* Griff. : Plants grow sometimes singly or mixed with other mosses in moist and shaded slopes of soil covered rocks and on loamy soil at circular road (Ootacamund) 2600 metres or in Bear Shola (Kodaikanal) 2300 metres. Plants dark green and prostrate (Fig. 154): Leaves (Fig 155) tongue-like, oblong 6.5 mm to 7 mm long and 2.5 mm to 3 mm broad with a thick undulate margin and strong costa; apex (Fig. 156) obtuse, nearly mucronate above; leaf-cells roundish 4 to 5 in a square of 88μ (Fig. 157). Sporophyte termi nal or lateral; seta erect and elongated 40 mm to 42 mm long; capsule (Fig. 158) inclined 10 5 mm to 11 mm × 1.2 mm to 1.3 mm, lid conical; peristome teeth 16 free;

spores (Fig. 402) spherical with a thick coat, small, 12μ to 14μ in diameter.

Kabiersch (1937) treated this as a variety of *Mnium longirostrum* Brid. (*M. rostratum*). H. Ando (1961) says that this is closely related to Japanese *M. maximowiczii* Lindb.

Rhizogoniaceae

27. *Rhizogonium spiniforme* (Hedw.) Bruch. : Plants grow on tree trunks in close tufts in the Priests' Walk (Kodaikanal) 2250 metres. Plants bright green, 3 cm to 4 cm tall (Fig. 160). Leaves (Fig. 161) narrow lanceolate 6 mm to 7 mm long and .4 mm to .5 mm broad at base, margin serrate; apex (Fig. 162) acuminate; leaf-cells thick walled, rectangular near the mid-rib and round or ovate towards the margin; 4 to 5 cells in a square of 22μ (Fig. 163), Sporophyte terminal or lateral; seta erect 35 mm to 37 mm long, reddish brown; capsule (Fig. 164) inclined or horizontal 6 mm to 6.2 mm × .9 mm to 1 mm, elongate-ellipsoidal; operculum (Fig. 375) conical, long beaked; peristome double, outer phase of peristome characteristic of Diplolepideae (Fig. 165), inner phase of peristome with fimbriae-like margin (Fig. 166) and horizontal striations; spores spherical 15μ to 17μ in diameter.

Bartramiaceae

28. *Bartramia madurensis* Dix. and Vard.*: Plants pale green, grow well in cushions to a height of 2.5 cm to 3 cm without sporophyte in the soil coverd rocks of the municipal Park of Kodaikanal 2800 metres

(Fig. 167). Soil acidic, pH being 4.5 to 4.6. Leaves (Fig. 168) from a broad base abruptly narrow into a long subulate tip; 4 mm to 4.5 mm. long and .5 mm to .7 mm broad at base; apex (Fig. 169) drawn out to a very fine point with serrate margin; leaf-cells mamillate elongated and thick walled (Fig. 170), costa very broad, cells narrow and closely packed, marginal rows of cells rectangular.

29. *Philonotis anisoclada* Card. and Vard.: Plants yellowish green, grow in dense tufts 3 cm to 3.5 cm tall (Fig. 171) in the swampy soil near mountain streams of Shembaganur (Kodaikanal) 2150 metres or at Thoddabedda shola, (Ootacamund) 2800 metres. Stem erect 2 cm to 2.5 cm and branches profusely (5 to 6) from the same point. Rhizoidal felt dense extending from the base upwards on the stem. Leaves (Fig. 172) lanceolate .8 mm to 1.2 mm long and .3 mm to .4 mm broad at base, costa strong extending upto the tip; apex (Fig. 173) prolonged into a hair point, margin towards the apex serrated; laminar cell (Fig. 174) collenchymatous, thick walled and elongated; cells of the costa and margin much thick walled. Sporophyte terminal; seta reddish 30 mm to 32 mm long; capsule (Fig. 176) erect or inclined, sub-spherical 2.5 mm to 2.6 mm $\times$ 1.5 mm to 1.7 mm when dry longitudinally furrowed; operculum sharp conical (Fig. 376); peristome (Fig. 177) free 75μ to 88μ long and 30μ broad at base; spores (Fig. 405) large spherical, granulose 20μ to 22μ in diameter.

Orthotrichaeae

30. *Hypnodon perpusillus* (Thw. and Mitt.) C. M.: Plants very small, with sporophyte less than 1 cm tall

(Figs. 178&179); grow on barks of rotting tree trunks at Perumal hill (Kodaikanal) 1600 metres. Leaves (Fig. 180) from oblong or spatulate base passing into an upper elliptic part; costa ending at some distance from the leaf tip; laminer cells (Fig. 181) rectangular 55μ to 22μ and isodiametric and roundish above; apex (Fig. 182) acute. Sporophyte terminal: seta 2 mm to 2.5 mm long; capsule ovoid, 8-ribbed 1 mm to 1.2 mm × .4 mm to .5 mm, perichaetium almost inseparable from sporophytic foot; operculum conical and beaked (Fig. 377); peristome teeth connate in pairs (Fig. 183) 176μ long and 66μ broad at base; spores (Fig. 407) large, spherical with a thick coat 19μ to 22μ in diameter.

31. *Schlotheimia grevilleana* Mitt. : Plants growing predominantly on rock in Priests' Walk (Kodaikanal) 2250 metres forming thick carpet with bright yellowish younger parts. Axis creeping, branching profusely: 2 cm to 2.5 cm tall fastigiate, densely foliose, main axis and branch stem below covered with felt of rhizoids (Figs. 184 & 185). Leaves (Fig. 186) elongate, oblong ending in a short point, 2.2 mm to 2.5 mm long and .6 mm to .75 mm broad: apex acute (Fig. 187); leaf-cells (Fig. 188) elliptic rectangular at base; ovate in the middle, cell walls much thickened, 5 to 6 cells in a square of 22μ (Fig. 189); isodiametric and sclerenchyma-like at apex (Fig. 190); rhizoids formed also from the base of the leaf. Sporophyte terminal on the branches; seta erect and short 8 mm to 9 mm long; capsule (Fig. 191) cylindric 2 mm to 2.1 mm × .9 mm to 1 mm ; calyptra long conical enveloping the capsule, margin lobed; peristome free, basal cells rectangular arranged in two rows, teeth

132μ long 15μ to 18μ broad at base (Fig. 192); spores (Fig. 408) spherical, 16μ to 18μ in diameter.

Trachypodaceae

32. *Trachypus bicolor* Rein. and Hornsch.*: Plants grow in dense tufts in the forests of Priests' Walk (Kodaikanal) 2800 metres in the shaded regions. Stem creeping on tree trunks branching profusely (Fig. 193), deep green in the older regions and yellowish green in the younger parts. Leaves (Fig. 194) lanceolate 1.5 mm to 2 mm long and .4 mm to .7 mm broad at base; apex acuminate (Fig. 195); leaf cells spindle-shaped and elongated (Fig. 197), cells of costa narrower and thick-walled (Fig. 196).

33. *Trachypus humilis* Lindb. var. *humilis* Zanten. *: Plants grow in close tufts on trees in the sholas of Shembaganur (Kodaikanal) 2000 metres. Axis of this hairy moss very thin, branchlets many (Fig. 198). Leaves (Fig. 199) small, lanceolate with broad base .9 mm to 1.1 mm long and .25 mm to .3 mm broad at base; apex drawn out into a long narrow hair point (Fig. 200), cells linear and thick-walled above (Fig. 203), luman of the cells very narrow; alar cells irregularly shaped (Fig. 202); no mid-rib seen in the leaf, except that at the base where the cells diverge out above.

34. *Trachypodopsis serrulata* (Beauv.) Fleisch. var. *crispatula* (Hook.) Zanten. * : Plants grow on trees in tufts in the Priests' Walk (Kodaikanal) 2300 metres and on forest ground in Kern hill (Ootacamund)

2650 metres. Secondary stems numerous, flexuosely ascending with closely arranged leaves (Fig. 204). Leaves (Fig. 205) 3 mm to 3.75 mm long and .5 mm to .75 mm broad lanceolate and elongate with serrate margin; apex ending in a narrow acumen (Fig. 206); leaf-cells (Figs. 207 & 208) elongated elliptic with much thickened cell walls; costa well defined; the lumen of the alar cells elongated oval (Fig. 209) and spindle shaped just above.

Myuriaceae

35. *Myurium warburgii* (C. M.) Fleisch.* : Plants compactly tufted, growing in the shaded and moist forests of Tiger shola (Kodaikanal) 2000 metres, branching irregularly with crowded brownish green leaves (Fig. 210). Leaves (Fig. 211) narrow lanceolate 3 mm. to 4 mm long .3 mm to .75 mm broad at base; upper margin serrulate; apex (Fig. 212) acuminate and drawn out into a fine point, leaf-cells (Fig. 213) narrow and irregularly spindle– shaped above and broadly rhomboid below (Fig. 214).

Pterobryaceae

36. *Pterobryopsis orientalis* (C. M.) Fleisch.* : Plants grow on tree trunks and on the branches in the moist woods of Silver cascade (Kodaikanal) 2000 metres. Primary stem creeping and spreading, branchlets yellowish green (Fig. 215). Leaves (Fig. 216) ovate oblong, shortly narrowed up, 1 mm to 2 mm long and .8 mm to 1 mm broad; leaf cells (Fig. 217) spindle-shaped 10 to 12 cells in a square of 88μ, towards the middle the cells narrowly rhomboid 70μ to 90μ × 5μ to 6μ; alar cells quadratic

to ovate (Fig. 218); costa extending only up to half the leaf.

Meteoriacae

37. *Papillaria crocea* (Hamp.) Jaeg.: Plants pale green, thread-like growing on branches of trees in the shaded moist forests of Four-road shola (Ootacamund) 2650 metres, Tiger shola (Kodaikanal) 2500 metres. Primary stem thin and hanging in the form of festoons, secondary branches not very long but numerous, irregularly pinnate (Fig. 219 and frontispiece). Leaves closely adpressed on the stem, ovate auriculate (Fig. 220) .8 mm to 1.2 mm long and .5 mm to .7 mm broad; apex gradually acute (Fig. 221); costa strongly developed; laminar cells with roundish ovate lumen, 6 cells in a square of 22μ (Fig. 222). Sporophyte lateral, drooping from the branches: seta short 5 mm to 6 mm long; capsule cylindric 2.3 mm to 2.5 mm long and 1 mm to 1.2 mm in diameter; operculum (Fig. 378) conical and beaked; peristome teeth slender; spores spherical with a thick coat (Fig. 409) 16μ to 19μ in diameter.

38. *Aerobryopsis longissima* (Doz. and Molk.) Fleisch. *: Plants grow on tree trunks and on rocks, irregularly branching, secondary stems foliose (Fig. 223) in the Tiger shola (Kodaikanal) 2100 metres. Leaves (Fig. 224) broadly lanceolate 3 mm to 5 mm long and .6 mm to .75 mm broad; apex (Fig. 225) very long, gradually attenuated into a fine point; leaf-cells (Fig. 226) rhomboid 6 to 7 in a square of 22μ.

39. *Barbella tenax* (C. M.) Broth. *: Plants mostly growing on branches in drooping tufts in the Tiger shola (Kodaikanal) 2100 metres or in the Four-road shola (Ootacamund) 2650 metres; branches pinnate and long, younger portions yellowish green and less foliose (Fig. 227). Leaves (Fig. 229) ovate oblong 2 mm to 2.5 mm long and .5 mm to .75 mm broad, lower margins incurved; costa absent, point of attachment with a thickening; apex (Fig 228) short acuminate with serrate margin; laminar cells (Fig 230) very narrow and elongated, spindle-shaped, 65μ to 85μ long and 5μ to 7μ wide.

40 *Barbella determessi* (Rein. and Card.) Fleisch. *: Plants grow on the branches of trees and hang down in the forests of Silver cascade (Kodaikanal) 2000 metres or in Lovedale shola (Ootacamund) 2300 metres. Primary stem very long, pinnately branching (Fig. 231). Leaves (Fig. 232) of the branches spreading, lanceolate 3.5 mm to 4 mm long and .4 mm to .5 mm broad at base; stem leaves adpressed to the axis, narrowly linear lanceolate; apex (Fig. 233) prolonged acuminate with slightly toothed margin; mid-rib absent; laminar cells (Fig. 234) narrowly linear and spindle-shaped.

41. *Barbella pendula* (Sull.) Fleisch.*: Plants creep along the bark of tree trunks and branches in the forest of Priests' Walk (Kodaikanal) 2300 metres. Primary stem fimbriate with numerous branches, long and hairy (Fig. 235). The pH of the sediment in the crevices of the bark is 6.0. Leaves (Fig. 236) spreading only on the primary stem and lower regions of the branches, lanceolate 1.5 mm to 2 mm long and .5 mm to .7mm

broad ; margin serrate ; mid-rib wanting, narrow and thick walled cells closely packed at the point of attachment, indicative of costa ; apex (Fig. 237) prolonged, acuminate, ending bluntly ; laminar cells (Fig 238) broad, linear rhomboid 44μ to 46μ long and 7μ to 8μ wide.

42. *Floribundaria floribunda* (Doz. and Molk.) Fleisch.* : Plants grow with other mosses in the thick forests of Lovedale shola, 2300 metres, Four road shola 2650 metres (Ootacamund) and in the Park-shola (Kodaikanal) 2350 metres. Primary axis threadlike, branches and secondary branches bear spreading leaves (Fig. 239) Leaves (Fig. 240) broad at base and slightly auricled, lanceolate 1.6 mm to 2mm long and .5 mm to .75mm broad ; apex (Fig. 241) prolonged acuminate laminar cells (Fig. 242) narrowly linear, cell walls very much thickened.

43. *Meteoriopsis squarrosa* (Hook.) Fleisch * : Plants grow with other mosses in the thick forests of Lovedale shola, 2300 metres, Four-road shola 2650 metres (Ootacamund) and in the Park-shola (Kodaikanal) 2350 metres. Primary stem creeps on the bark of tree trunks and on the branches ; secondary stems numerous and drooping (Fig. 243). Leaves (Fig. 244) stem clasping squarrose, crowded, basal part broad, sub-rniform 3 mm to 3.5 mm long and 1 mm to 1.5 mm broad ; mid-rib absent; apex (Fig. 245) shortly acuminate with sparsely-toothed margin; laminar cells (Fig. 246) long spindle-shaped, cell walls thickened.

44. *Meteoriopsis reclinata* (C.M.) Fleisch.: Plants grow in dense tufts on branches of moist forest trees

in the Priests' Walk (Kodaikanal) 2200 metres, and Four-road Shola (Ootacamund) 2300 metres. Primary axis long, creeping or drooping in the form of festoons. Secondary pinnate branches short and numerous with spreading leaves (Fig. 247 and frontispiece). Leaves 2.5 mm to 3 mm long and 1 mm to 1.2 mm broad at base, recurved, falcately secund, stem-clasping (Fig. 248); mid-rib absent; apex acute with toothed margin (Fig. 249); laminar cells (Fig. 250) narrow but long elliptic with tapering ends, cell walls incrassate.

Neckeraceae

45. *Homaliodendron exiguum* (Bryol. Jav.) Fleisch.*: Plants grow on the barks of decaying tree trunks in the damp forests of Priests' Walk (Kodaikanal) 2300 metres. Axis slender 3 cm to 5 cm tall (Fig. 251). Leaves (Fig. 252) bifarious ovate oblong .8 mm to .1 mm long .25 mm to .3 mm broad, apex orbicular obtuse: mid-rib wanting; laminar cells (Fig. 253) quadratic to roundish, 4 to 5 cells in a square of 22μ.

46. *Homaliodendron flabellatum* (Dix.Sm.) Fleisch.*: Plants sturdy and dark green growing on the trunks of trees and on moist rocks, rupestral and spreading horizontally. Axis strong, without leaves, branches two-ranked, shoot remarkably flattened (Fig. 254). Leaves bifarious on the branches, oblong, mid-rib not extending up-to tip; apex broad, upper margin irregularly toothed (Fig. 255); leaf-cells (Fig. 256) quadratic to roundish 3 to 4 cells in a square of 22μ. Gemmae bud like in the leaf axils.

47. *Distichophyllum succulentum* (Mitt.) Broth. * : Plants grow in densely shaded and moist shelters of forest ground of Perumal hill (Kodaikanal) 2000 metres and of Kotagiri (Ootacamund) 2000 metres. Plants 2.5 cm to 3 cm tall and dark green (Fig. 257). Leaves (Fig. 258) more than twice long as broad, 2 mm to 2.5 mm long and .6 mm to .75 mm broad; costa excurrent slightly; marginal layer formed apex (Fig. 259) sharply retuse; laminar cells (Fig. 260) isodiametric and pentagonal, each cell 22μ × 22μ.

Hookeriaceae

48. *Hookeria acutifolia* Hook. *: Plants grow in moist and shaded forest ground of Thoddabedda slope (Ootacamund) 2800 metres. Plants pale green; leaves arranged in 4 or 5 rows (Fig. 261). Leaves (Fig. 262) ovate, broad and elliptic 3.5 mm to 4 mm long and .7 mm to 1 mm wide; marginal seam well formed; mid-rib absent; apex (Fig 263) angularly acute; leaf cells rhomboid 33μ × 11μ.

Hypopterygiaceae

49. *Hypopterygium tenellum* Lac. = *H. ceylanicum* Mitt. * : Plants grow on rotting tree trunks in moist and shaded forests of Priests'Walk (Kodaikanal) 2500 metres. Primary stem creeps in the crevices of rocks and bark of trees; secondary branches profuse, flat and spreading Fig. 264). Leaves (Fig. 265) ovate oblique, .9 mm to 1.1 mm long and .5 mm to .7 mm wide ; mid -rib ending at some distance below the leaf-tip and running on one side dividing the lamina into unequal

halves; upper margin serrulate; laminar cells (Fig. 266) rhomboid hexagonal 5 to 6 cells in a square of 88μ.

Leskeaceae

50. *Rhegmatodon orthostegius* Mont. : Plants grow' on the twigs of small trees in moist forests of Priests Walk (Kodaikanal) 2500 metres and in the Wood-house shola (Ootacamund) 2600 metres. Secondary stems irregularly branched, branches ascending to erect (Fig 268). Leaves (Fig. 269) ovate 1 mm to 1.5 mm long .4 mm to .6 mm wide; apex acute (Fig. 267); mid-rib not extending up-to the tip; leaf-cells (Fig. 270) quadratic at base, ovate in the upper portion, lumen much reduced on account of cell wall thickening, 3 cells in a square of 22μ in the middle of the lamina. Sporophyte terminal or lateral on the branches : seta reddish 6 mm to 8 mm long and erect; capsule (Fig. 271) 2 mm to 2.2 mm × .9 mm to 1 mm cylindric; operculum conical (Fig. 379); peristome (Fig. 274) free, inner peristome slender and long (Fig. 273); spores (Fig. 410) large, spherical 19μ to 21μ in diameter. Stomata found on the wall in the apophysis region of the capsule (Fig. 272).

Thuidiaceae

51. *Herpetineurum toccoae* (Sull. and Lesq.) Card: * Plants grow on tree trunks or soil covered rocks in the woods of Bombay shola (Kodaikanal) 2400 metres. Primary stem creeps along horizontally and secondary stems erect 4 cm to 5 cm tall, branches spreading

(Fig. 275). Leaves (Fig. 276) lanceolate 2.5 mm to 3 mm long and .7 mm to 1 mm wide at base; upper margin serrate (Fig. 277); leaf cells (Fig. 278) very small and sub-quadratic to round or ovate, 6 to 7 cells in square of 22μ.

52. *Thuidium tamariscellum* (C.M) Bryol. : Plants grow very well in the damp shady forest ground of Bear Shola (Kodaikanal) 2300 metres in matted tufts. Primary stem hardy, secondary stems branch thrice. This tri-pinnate branching and flattaned frond like form characteristic of this moss (Fig. 279). Branch leaves (Figs. 280 & 281) ovate .15 mm to .2 mm long and .08 mm to .1 mm broad; stem leaves larger, cordate (Figs. 282 & 283) .8 mm to 1 mm long and .4 mm to .5 mm broad; both leaves with finely toothed upper margin; branch leaf-cells (Fig. 284) 3 to 4 in a square of 22μ, papillose, thick walled; stem leaf-cells rhomboid at alar region (Fig. 287). Sporophyte lateral on branches : seta reddish, erect or inclined, smooth, 15 mm to 17 mm long; capsule 2.7 mm to 3 mm × .7 mm to .9 mm ellipsoidal (Fig. 285); operculum (Fig. 380) cupula-shaped and beaked; peristome free with longitudinal striations (Fig. 286); spores (Fig. 411) spherical 12μ to 14μ in diameter.

Brachytheciaceae

53. *Pleuropus nilghiriense* (Mont.) Toyama: Plants grow on tree trunks in the damp shaded Tiger Shola (Kodaikanal) 2150 metres. Plants (Fig. 288) brownish green, secondary branches numerous and spreading 4 cm

to 5 cm tall. Leaves (Fig. 289) lanceolately acuminate 1.2 mm to 2 mm long and .4 mm to .5 mm broad at base; upper margin (Fig 290) sharply serrate; laminar cells (Fig. 291) elongated and narrow, 40μ to 45μ long and 4μ to 6μ wide. Sporophyte lateral: seta long, red, and erect 8 mm to 10 mm long; capsule cylindric (Fig. 292) 2 mm to 2.2 mm $\times$ .5 mm ; operculum conical with long beak; peristome (Fig. 293) 120μ long and blunt 45μ broad at base with a middle striation; spores spherical, 15μ to 17μ in diameter.

54. *Rhynchostegium javanicum* (Bel.) Besch. : Plants 3.5 cm to 4.5 cm tall, light green, grow on-moist ledges where earth has accumulated and in the Tiger Shola 2100 metres and in the Priests' Walk (Kodaikanal) 2300 metres. Secondary stems branching (Fig 294). Leaves (Fig 295) apparently two-ranked 2 mm to 2.5 mm long and .7 mm to 1 mm broad, ovate lanceolate, upper margin serrulate apex (Fig. 296) acuminate; laminar cells (Fig. 297) narrow and much elongated, upper cells spindle-shaped. Sporophyte lateral : seta 18 mm to 20 mm long ; capsule (Fig. 298) horizontal cylindric 4 mm to 4.2 mm $\times$ .7 mm to .9 mm ; lid arched conical (Fig 381) ; peristomial teeth very long 2.7 mm upper part bent inwards (Fig. 299) : spores (Fig. 412) small spherical, 8μ to 10μ in diameter.

Entodontaceae

55. *Erythrodontium julaceum* (Hook.) Par. : Plants grow horizontally on trees and shrubs, or on moist rocks in the Priests' Walk (Kodaikanal) 2350 metres. Plants long, secondary branches numerous 4 cm to 6 cm

tall (Fig. 300). Rhizoids unbranched, numerous in clusters from the axis in different regions. Leaves broad, ovate (Fig. 301), slightly concave 1 mm to 1.5 mm long and .7 mm to .9 mm broad; apex sub-abruptly acuminate (Fig. 302), upper margin toothed; alar cells (Fig. 303) particularly marginal and sub-marginal ones ovate to quadratic, hardly wider than the inner cells which are elongated and rhomboid; upper cells spindle-shaped with thick walls (Fig. 304). Sporophyte lateral; seta 18 mm to 25 mm long; capsule (Fig. 305) erect, prolate, sphaeroidal 1.5 mm to 1.7 mm × .9 mm to 1.2 mm; lid conical; peristome (Fig. 306) sharp 66μ long and 16μ board at base; spores large, spherical 18μ to 21μ in diameter.

Sematophyllaceae

56. *Foreauella indica* Dix. and Vard.* : Plants grow on soil covered rocks or tree trunks in Shenbaganur (Kodaikanal) 2000 metres. Primary stem grows horizontally and numerous branches 4 cm to 5 cm long (Fig. 307) grow vertically. Stem leaves (Fig 308) adpressed, obovate, trapezoidal; apex acuminate .9 mm to 1.2 mm long and .4 mm to .6 mm broad; alar cells oblong upper leaf cells (Fig 309) elongate rhomboid 32μ × 22μ.

* The specific name of this plant (56) in current use is *Foreauella orthothecia* (Schw.) Dix. and Vard. according to E. B. Bartram. H. Ando points out that *Foreauella indica* is only a synonym of *Foreauella orthothecea*. This is referred to as a South Indian genus after the name of Rev. Father G. Foreau, who was kind enough to show the author this plant in its natural habitat in the Sacred Heart College Garden at Shenbaganur, Kodaikanal in 1959.

57. *Sematophllum subhumile* (C. M.) Fleisch. : Plants grow on moist rock in shaded forests of Shenbaganur (Kodaikanal) 2000 metres. Primary stem creeps horizontally 5 cm to 6 cm long; irregularly pinnate branches spreading (Fig. 311). Leaves (Fig. 312) not adpressed even when dry, long lanceolate 1.5 mm to 2 mm long and .4 mm to .5 mm broad; apex acuminate ending in a fine point; leaf cells narrow, elongated, spindle-shaped 60μ to 64μ × 6μ to 7μ (Fig. 313), upper cells narrow linear (Fig. 314). Sporophyte lateral. seta 10 mm to 12 mm long; capsule (Fig. 315) inclined elongate ellipsoidal 15. mm to 1.7 mm × .3 mm to .5 mm; operculum (Fig. 382) cupula-shaped, beak long; peristome (Fig, 316) 1.75 mm long; spores (Fig. 413) small spherical 9μ to 10μ in diameter, with a thick coat. Gemmae in the form of vegetative buds found in the leaf axil.

58. *Warburgiella leptorrhynchoides*(Mont.)Fleisch *.: Plants: pale yellowish green, grow on the rocks in the forest of Tiger shola (Kodaikanal) 2C00 metres. (Fig. 317) spreading horizontally with numerous branches. Leaves (Fig. 318) ovate oblong 1.2 mm to 2 mm long and .2 mm to .4 mm ; apex (Fig. 319) ending in a narrow acumen; margin of the leaf incurved and entire at base, but obscurely denticulate near the tip; laminar cells (Fig. 320) narrowly linear 66μ long and 7μ to 8μ broad: alar cells inflated.

Hypnaceae

59. *Hypnum cupressiforme* Hedw.*: Plants prostrate, on forest ground or on decaying wood in Bear Shola

(Kodaikanal) 2300 metres (Fig. 321) branching pinnately and forming flat carpets. Leaves (Fig. 322) ovate lanceolate 2mm to 2.5mm long and .4mm to .6 mm broad at base ; apex reflexed and secund (Fig. 223) acumen to a point; mid-rib absent; leaf-cells (Fig. 324) narrow and elongated 50μ to $66\mu \times 5\mu$ to 6μ, cells towards the middle of the leaf slightly more elongated with tapering ends cell walls much thickened. Simple rhizoids found to arise from the base of the leaves also.

60. *Taxiphyllum taxirameum* (Mitt.) Fleisch. : Plants grow on the bark of trees in moist forests of Priests' Walk (Kodaikanal) 2350 metres. Primary axis creeps on the bark and branches vertical on upper side (Fig. 325). Leaves (Fig. 326) ovate oblong 1.25 mm to 1.75 mm long and .3mm to .5mm wide ; apex (Fig. 327) long acuminate ; leaf cells isodiametric, 3 cells in square of 22μ (Fig. 328) lumen of upper leaf cells very small.

61. *Ctenidium lychnites* (Mitt.) Broth. : Plants grow on moist ground or on tree trunks in the woods of Priests' Walk (Kodaikanal) 2350 meteres. Primary stem prostrate, branching pinnately 2 cm to 2.5 cm tall (Fig. 329). Stem leaves cordate ovate, rapidly narrowed into a lanceolate upper part. Branch leaves narrower, elliptic (Fig. 330) 1 mm to 1.5mm long and .4 mm to .5 mm broad : apex (Fig.331) acuminate ; margin serrate ; leaf-cells linear, elongated and narrow (Fig. 332). Sporophyte lateral : seta erect and inclined above 25mm to 27mm long; capsule (Fig. 333) elongated ovoid, horizontal 6.5 mm to 7mm. × 1.3 mm to 1.5 mm; lid conical with sharp beak (Fig. 383); peristome (Figs. 334 and 335) 2.75 mm

to 3 mm long with a central dividing line up-to some distance from the base. spores spherical 12μ to 13μ in diameter.

Polytrichaceae

62. *Atrichum aculeatum* Card. and Vard.: Plants grow in dark green dense tufts and cushions on forest ground especially under the shade near tree trunks in the damp forests of Thoddabedda (Ootacamund) 2500 metres, or near St. Mary's Hill 2600 metres, or in rich humus soil of Bombay Shola 2800 metres (Kodaikanal), to a height of 2 cm to 3 cm (Fig 336). Soil acidic pH being 5.6 to 5.8; Leaves (Fig. 337) keeled, linear 10 mm to 11 mm long and 1.2 mm to 1.5mm broad with a marginal rim, upper margin serrate; apex acute; basal leaf-cells isodiametric to hexogonal 22μ to 33μ $\times$ 22μ (Fig. 338); upper leaf cells roundish (Fig. 339); costa prominent with narrow linear and elongated cells. Sporophyte terminal or on the branches: seta long, reddish, erect 25 mm to 27 mm; capsule inclined 5 mm to 6.5 mm $\times$ 1.2 mm to 1.5 mm cylindrical, slightly curved; (Fig 340) operculum (Fig. 384) short, conical and beaked peristome (Fig. 341) teeth 16, blunt, 110μ long and 44μ broad; spores (Fig. 414) spherical 15μ to 17μ in diameter.

63. 63. *Pogonatum microstomum* (R. Br.) Brid.: Plants gregarious, strong and sturdy growing on the crevices of culverts, or on stone walls or on moist grounds, in Kodaikanal and in Ootacamund at all altitudes between 2000 metres to 2700 metres. Gametophyte alone very tall 10 cm to 15 cm lower part of the stem rhizomatoid (Fig. 342). Leaves (Fig. 343) linear 8 mm to 11 mm long and 1 mm to 1.5 mm broad and 44μ thick; apex (Fig. 344) convex, margin toothed;

cells of the margin quadratic, those of the leaf sheath rectangular (Figs. 345 & 349); mid-rib cells narrow linear; leaf in transverse section resembling that of *Marchantia* thallus (Fig. 349), many cells thick, lamellate.; Sporophyte terminal or lateral: seta erect 65 mm to 70mm long; capsule 5 mm to 5.5mm × 1.8 mm to 2 mm roundish, ellipsoidal: operculum broad, cupula-shaped and short beaked; calyptra hood shaped producing a dense felt of hairs enveloping the capsule; peristome teeth 32 with blunt end, 286μ × 110μ (Figs. 347 & 348); spores (Fig. 415) greenish, spherical 12μ to 14μ in diameter.

64. *Pogonatum neesii* (C.M.) Mitt.: Plants grow in dense tufts on the road-side cuttings to Thoddabedda (Ootacamund) 2800 metres or around St. Mary's Hill (Kodaikanal) 2600 metres. Soil acidic, pH being 5.6 to 5.8. Gametophytes 2 cm to 5 cm tall, not as tall as *Pogonatum microstomum*. Plants gregarious 4 cm to 7 cm tall (Fig. 350). Leaves (Fig. 351) whorled on the stem, linear 4 mm to 8 mm long 1 mm to 1.5 mm broad and 40μ to 44μ thick; apex acute with serrate margin (Fig. 352); leaf sheath cells (Fig. 353) quadratic at base, roundish above, cells of the costa elongated and narrow; leaf in transverse section resembles that of the thallus of *Marchantia* (Fig. 354) multicellular in thickness, lamellate. Sporophyte terminal: seta erect 35 mm to 40 mm long; capsule (Fig. 355) round, erect, elliptic 4 mm to 4.5 mm × 1.5 mm to 2 mm; lid conical, beaked (Fig. 385); calyptra hood-shaped giving rise to long hairs forming a felt; subjacent this hair-cap calyptra short thin cuculate inner calyptra also present; peristome with 32 teeth (Fig. 356); spores (Fig. 416) spherical, greenish 9μ to 12μ in diameter.

General considerations

After Hedwig (1864) who has left magnificent illustrations of mosses, several Bryological Floras and Manuals have appeared from different parts of the world. Steere (1950, 1952) has reviewed some of these treatments. Outstanding contributions on Moss Flora have been made by Brotherus(1924). Dixon (1904), Grout (1924,) 1928–1940), Bartram (1939, 1949), Jennings (1951), Dunham (1951), Jensen (1939), Krusenstijerna (1945) and Watson (1954) have produced monumental works. These however, are mainly systematic descriptions of the mosses occurring in different regions of the world. Ruhland (1924) has given a detailed account of the life-history of the mosses in general.

The general considerations on the external morphology of the South Indian mosses dealt with in this study, are based upon original observations both in the field and the laboratory. In most cases they are in conformity with the observations of previous workers.

a) *The Leaf*

Most of the Bryologists have taken into account the character of the leaves as one of the most important keys for the identification of the mosses (Dixon, 1904),

(Dunham, 1951). It has been considered very important even in the determination of sterile mosses. Full grown and well developed leaves alone were taken up for detailed study.

The phyllotaxy

The mode of arrangement of the leaves on the stem is also equally important. The usual arrangement in most cases is spirally alternate. The leaves are distichous in *Fissidens* (Figs. 1 & 2). In *Hypnum* (Fig. 322) the leaves are curved and turned in opposite directions giving a braided appearance, and in *Bryum* (Fig. 145) they are adpressed to the stem, so compactly dove-tailed that the lower leaves almost encircle the upper ones. The number and size of the leaves on the main and secondary axes vary considerably in the pleurocarpous mosses. In *Homaliodendron flabellatum* (Fig. 254) the leaves occur only on the branches but not on the main axis when they are old. In *Thuidium tamariscellum* (Figs. 280 & 281) the leaves of the main axis are larger than those of the branches. Watson's (1954) statement that the leaves of the finer branches are often different in shape from those of the main stem, is true of this moss also.

The shape

The shape of the moss leaf varies greatly in different species. Some are long and narrow as in *Ditrichum amoenum* (Fig. 9), lanceolate as in *Philonotis anisoclada* (Fig. 172), ligulate in *Mnium coriaceum* (Fig. 155), falcate in *Meteoriopsis squarrosa* (Fig. 244), linear in *Myurium*

and *Thysanomitrium* (Figs. 211 & 29) and nearly orbicular in *Homaliodendron exiguum* (Fig. 252). Sometimes the shape is such as to combine a few terms for describing them such as linear-lanceolate in *Rhizogonium spiniforme* (Fig. 161) or ovate-oblique in *Hypopterygium tenellum* (Fig. 265). The mid-rib is usually present in many of the mosses but it is characteristically absent in some such as *Barbella tenax* (Fig. 229), *Floribundaria floribunda* (Fig. 240), *Meteoriopsis squarrosa* (Fig. 244). In a few cases the mid-rib ends blindly half way as in *Distichophyllum succulentum* (Fig. 258) and in *Hypopterygium tenellum* (Fig. 265), whereas in certain others it is continued up almost to the apex as in *Thuidium tamariscellum* (Figs. 280 & 282) and *Pleuropus nilghiriense* (Fig. 289). Lamella on leaves is characteristic of Polytrichaceae.

The margin

The margin of the leaves varies very much. This diagnostic character is of immense value in the identification of the species. There is entire margin in *Campylopus nodiflorus* (Fig. 21), undulate in *Mnium coriaceum* (Fig. 155), serrate in *Rhizogonium spiniforme* (Fig. 161) serrulate in *Trachypodopsis serrulata* (Fig. 205) and denticulate in the upper part of *Mnium coriaceum* (Fig. 157). There are also cases in which the lower part may be entire and the upper part toothed as in *Rhodobryum giganteum* (Fig. 152).

The apex

The apex of the leaf is also of equal importance in mosses for specific determination. It may be acumi-

-nate as in *Trachypus humilis* (Fig. 200), acute in *Hookeria acutifolia* (Fig. 263), and terete and excurrent in *Tortula muralis* (Fig. 63) and apiculate-retuse in *Distichophyllum succulentum* (Fig. 258).

The leaf cells

The cellular configuration and their arrangement in the leaves of the moss's is characteristic of the species. They are isodiametric in *Taxiphyllum taxirameum* (Fig. 328), rectangular in *Leucobryum* species (Figs. 52 & 59), rhomboid in *Anomobryum subniditum* (Fig. 142), papillose in *Thuidium tamariscellum* (Fig. 284) and narrowly elongate in *Sematophyllum subhumile* (Fig. 313). The alar cells are different from the cells of upper portions of the lamina not only in size but in form as well. The shape of the cells in different parts of the lamina is also variable in *Trachypus humilis* (Fig. 199, 201 to 203). The cells of the costa are usually different in size and shape from those of the lamina. They are elongated and narrow according to nature and thickness of the costa. The cell-walls in some mosses are thickened. In some they are so much thickened that the lumen is small or much reduced. Generally all the pleurocarpous mosses studied here, have long narrow cells throughout the lamina and in the acrocarpous mosses they are short and / or isodiametric in the upper portions and elongated rectangular at the base.

The nature of distribution of the chloroplasts is different in some mosses. The lower part of the leaf of *Bryum argenteum* is studded with chloroplasts while

the upper portion is so completely devoid of chloroplasts that it appears silver white and hence the specific name *argenteum* (Fig. 145). In *Leucobryum* the leaves are multilayered pale green and turn white when dry. The laminar cells are large and elongate some lacking chloroplasts. The leaves of the mosses in most cases are made up of only a single layer of cells except in the costa where it is multi-layered and also at the margin whenever it is thickened. The leaf of *Leucobryum* is thick and is more than one cell in thickness (Figs. 51 & 58); The leaves of *Pogonatum* species are thick or are perhaps the thickest of the lot. Longitudinal strips, the lamellae are closely arranged parallel to one another along the leaf. Dunham (1951) describes this costa as a wide mid-rib The anatomical details of these leaves are dealt with in the chapter on the Anatomical Observations: (Figs. 51, 58, 349 & 354).

In some mosses there is variation to a great extent in the size of the leaves in the same species. The leaves of the lower part of the axis and hence the old, and the well developed young leaves in the tender region are very much different in size though there is no variation in shape as judged from Length / Breadth ratio. The observations are tabulated as under:

TABLE - I

Name	Length of leaf in mm (L)	Breadth of Leaf in mm (B)	L/B ratio
1	2	3	4
Barbula indica	0.80	.50	1.6
	1.20	.75	1.6
	1.00	.65	1.6
	1.30	.80	1.6
	1.15	.70	1.6
	1.25	.75	1.6
	1.09	.67	1.6
	0.90	.54	1.6
	0.85	.50	1.6
	1.50	.90	1.6
	1.32	.82	1.6
	0.88	.55	1.6
Pogonatum microstomum	09.8	1.2	8.0
	08.0	1.0	8.0
	10.5	1.3	8.0
	08.8	1.1	8.0
	09.6	1.2	8.0
	12.0	1.5	8.0
	09.5	1.2	8.0
	09.7	1.2	8.0
	12.0	1.5	8.0
	11.3	1.3	8.0
	10.4	1.3	8.0
	11.2	1.4	8.0

TABLE I (Contd.)

1	2	3	4
Pogonatum neesii	5.0	1.0	5.0
	6.0	1.2	5.0
	5.5	1.1	5.0
	4.0	0.8	5.0
	8.0	1.6	5.0
	7.5	1.5	5.0
	7.5	1.5	5.0
	6.6	1.3	5.0
	6.5	1.3	5.0
	6.0	1.2	5.0
	5.5	1.1	5.0
	6.5	1.3	5.0
Rhodobryum giganteum	08.8	4.0	2.2
	10.0	4.5	2.2
	10.2	4.6	2.2
	09.5	4.2	2.2
	09.9	4.5	2.2
	07.2	3.2	2.2
	09.7	4.1	2.2
	07.8	3.5	2.2
	08.4	3.8	2.2
	11.0	4.8	2.2
	08.2	3.7	2.2
	06.7	3.0	2.2

It may thus be seen that in spite of variation in the size of the leaves in these mosses, the L/B ratio of each species is a constant factor.

However, in the following two species the L B ratio of the leaves is variable :

TABLE - II

Name	Length of Leaf in mm (L)	Breadth of Leaf in mm (B)	L/B ratio
Fissidens schimidii	0.88	.09	9.7
	0.99	.10	9.9
	1.10	.11	10.0
	0.93	.10	9.3
	1.15	.11	10.4
	1.21	.13	9.3
	0.99	.12	8 3
	1.21	.13	9.3
	1.10	.12	9 1
	1.14	.13	8.9
Ditrichum amoeum	4.4	0.44	10.0
	4.8	0.32	15.0
	3.8	0.30	12.6
	4.3	0.30	14.3
	5.0	0.40	12 5
	5.3	0.42	12.6
	4.6	0.38	12.1
	4.1	0.40	10.2
	5.4	0.45	12.0
	6.0	0.45	13 3

(b) *The axis* :

The mosses are classified into two groups, the acrocarpi and the pleurocarpi. Although this division is not generally regarded as a natural one, according to Watson (1954), still it is convenient to retain it. In the former the capsule is normally borne at the apex of the primary axis or on its branch. The capsule arises laterally on the axis or on a short side branch in the pleurocarpous mosses. The length of the axis of the acrocarpous members is generally not very long, but that of the pleurocarpi is very long and may grow even to a maximum length of 2 metres, being found in *Papillaria crocea*. The smallest moss under this study is *Hypnodon perpusillus* which has been referred to as "*a pretty little moss*" by Bartram, its maximum height without sporophyte being 1.5 mm. The axis creeps inside the soil in some mosses as in the case of *Rhacomitrium javanicum*. It is very hardy in the fan moss, *Homaliodendron flabellatum*. Even the sturdy *Pogonatum microstomum* is not as hardy as this fan moss. There are also some mosses in which an axis "worth the name" is not organised as in *Ditrichum amoenum* and *Hypnodon perpusillus*.

The branching in the mosses is very variable. In the acrocarpi where the branches are not many, they arise from the primary stem as in *Bryum argenteum*, *Brachymenium exile* and *Pogonatum microstomum*. Profuse branching from the primary stem and growing above in close tufts can be seen in *Schlotheimia grevilleana*. Irregular but profuse branching are seen in *Myurium warburgii*, *Barbella tenax* and others.

The rhizoids usually arise from the base of the axis. There are also some mosses in which they arise from

any part of the primary axis or from the branches or from base or margin of the leaves. As Narayanaswamy (1957) has shown, they are produced from the seta or even from the base of the capsule. They are simple without any thickening and brownish in colour in most of the mosses They are profusely branched forming a felt in *Sclotheimia grevilleana* and are reddish in colour in this moss and also in *Rhizogonium spiniforme.*

It may be pointed out that axis of different types of mosses such as the terrestrial mosses, the rock mosses, and the tree mosses are typical in nature of their growth. The branching in the axis and the production of rhizoids in certain mosses are interesting

c *The sporophyte.*

Brotherus (1899) and Cardot and Varde (1925) have referred to a few of these mosses and have described the sporophytes. Again in his excellent contribution in Die Natürlichen Pflanzenfamilien, Brotherus, (1924) like a few other Bryologists, has taken into account the character of the sporophyte as the most important diagnostic feature in the indentification of mosses.

The foot

In all the available literature on the mosses, there seems to be no detailed account on the shape and nature of articulation of foot of the sporophyte to the gametophyte. In the present study sporophytes were available only in 34 species of mosses. The morphology of the foot has been brought to light for the first time for the these mosses. At present they have tentatively been classed under eight groups.

The fertilised egg develops into a sporophyte. This is differentiated into the foot, the seta and the capsule. The foot buried in the tip of the gametophore, could be separated with a pair of fine needles without causing any injury to it. However, it comes off easily when the perichaetial bract and the gametophore tissue are ripped open. Though the shape of the foot is generally attenuated in most of the cases they show the following 8 different forms:

1. Narrowly elongated to a blunt tip : e.g. in

   Hyophila involuta (Fig.422)
   Ditrichum amoenum
   Funaria hygrometrica
   Anomobryum subniditum
   Papillaria crocea
   Sematophyllum subhumile

2. Broadly narrowed down to a blunt tip: e.g. in

   Tortula muralis (Fig. 423)
   Funaria submarginata
   Pohlia flexuosa
   Rhodobryum giganteum

3. Conical and elongated : e.g. in

   Bryum argenteum (Fig. 424)
   Regmatodon orthostegius
   Pleuropus nilghiriense
   Erythrodontium julaceum

4. Sharply attenuated to a sharp point: e.g. in

Barbula indica (Fig. 425)
Trematodon ceylonensis
Brachymenium exile
Thuidium tamariscellum

5. Gradually narrowed to blunt and mamillate tip: e.g. in

Rhizogonium spiniforme (Fig 426)
Campylopus nodiflorus
Dicranodontium fragile
Leucobryum neilgherrense
Trichostomum cylindricum
Weisia macrospora

6. Flatly narrowed to blunt and undulate tip: e.g. in

Rhynchostegium javanicum (Fig 427)
Fissidens schimidii
Philonotis anisoclada
Hypnodon perpusillus

7. Bulging and napiform below: e.g. in

Atrichum aculeatum (Fig. 428)
Mnium coriaceum
Schlotheimia grevilleana

8. Abruptly narrowed to short tip: e.g. in

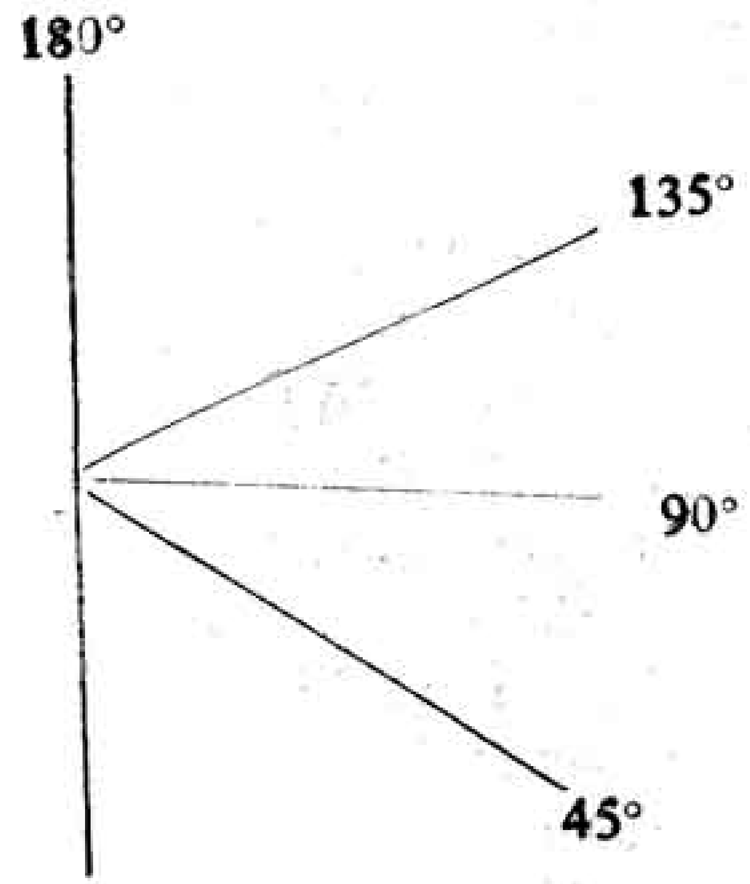
Pogonatum microstomum (F!g. 429)
Pogonatum neesii
Ctenidium lychnites

The Seta

The seta of the sporophyte is short in some and long in others, There appears to be no correlation or proportion between the length of the seta and the length of the axis or its branch. It is short but variously curled as in *Campylopus nodiflorus* where the length of axis is considerably long. In *Funaria hygrometrica* the seta is long, where the axis is short comparatively. The nature of looping of the seta is again very or extremely variable. There are different degrees* of looping of the seta. They may be grouped under two heads.

A. In this group the angle of looping is 135° and above. The capsules of these mosses are either slightly inclined or ercet. They are:

Ditrichum amoenum (180°)
Barbula indica (180°)



Schlotheimia grevilleana (180°)
Erythrodontium julaceum (180°)
Fissidens schimidii (180°)
Trematodon ceylonensis (155°)
Campylopus nodiflorus (140°)
Leucobryum neilgherrense (155°)
Trichostomum cylindricum (145°)
Weisia macrospora (50°)
Hyophila involuta (160°)
Tortula muralis (150°)
Funaria submarginata (170°)
Pohlia flexuosa (170°)
Brachymenium exile (140°)
Papillaria crocea (160°)
Philonotis anisoclada (140°)
Thuidium tamariscellum (160°)
Pleuropus nilghiriense (150°)
Rhegmatodon orthostegius (160°)

B. In this group the angle of looping is below 135°. The capsules of these mosses are much inclined or even dropping down. They are:

Rhodobryum giganteum (120°)
Mnium coriaceum (110°)
Rhizogonium spiniforme (100°)
Ctenidium lychnites (120°)
Pogonatum microstomum (105°)
Pogonatum neesii (125°)
Anomobryum subniditum (110°)
Sematophyllum subhumile (90°)
Pohlia flexuosa (50°)
Bryum argenteum (45°)

Rhynchostegium javanicum (55°)
Atrichum aculeatum (5°)
Philonotis anisoclada (20°)
Funaria hygrometrica (25°)
Dicranodontium fragile (10°)

The different degrees of looping of the seta in the two groups appear to have some bearing on the dispersal of spores. Spore dispersal is obviously regulated by the peristome. On closer examination, however, it has been found that the structure of the peristome in group A* is not as elaborate as the structure of the peristome in group B. This feature seems to conform to the prophetic statement of Jennings (1951): "Species whose capsules stand vertically are not so likely to have well-developed peristome as are species whose capsules are inclined or vertical, this variation corresponding to the need for the regulation of the spore dispersal."

As the degree of looping varies according to the age of the sporophyte, only well matured sporophytes were taken into consideration. Several observtions were made in each case in the foregoing classification. Further measurements of the length of the foot, seta and of the capsule were taken in the following manner: the length of the foot was measured from the point of attachment of the perichaetial bract down-wards. The length of the seta excluding the length of the foot buried in the gametophore and that of the capsule excluding the length of the operculum were measured The average of six readings in each case is tabulated (Table - III).

* In fact in ***Funaria snbmarginata*** the peristome is even **wanting.**

TABLE III

Name of moss	Length of foot in mm	Length of seta in mm	Length of capsule in mm	Breadth of capsule in mm	Diameter of spores in / μ
1	2	3	4	5	6
Fissidens schimidii	0.49	9.0	2.8	0.45	12
Ditrichum amoenum	0.83	8.5	2.3	0.45	16
Trematodon ceylonensis	0.99	22.5	8.0	0.62	23
Campylopus nodiflorus	0.91	9.0	1.6	0.92	16
Dicranodontium fragile	1.08	11.0	5.5	0.92	26
Leucobryum neilgherrense	0.66	4.5	3.2	0.84	19
Weisia macrospora	0.46	11.0	6.1	0.52	10
Trichostomum cylindricum	0.99	9 2	2.8	0.61	15
Hyophila involuta	0.99	11.0	2.8	0.62	9
Barbula indica	0.54	10.0	1.8	0.72	16
Tortula muralis	0.79	12.5	4.2	0.52	10

TABLE III (Contd.)

Name of moss	Length of foot in mm	Length of seta in mm	Length of capsule in mm	Breadth of capsule in mm	Diameter of spores in / μ
1	2	3	4	5	6
Funaria hygrometrica	0.83	48.0	4.0	0.92	10
Funaria submarginata	0.79	26.5	1.3	0.90	26
Pohlia flexuosa	0.66	32.0	7.0	0.92	16
Brachymenium exile	0.66	31.0	2.0	0.75	13
Anomobryum subniditum	0.66	30.5	2.6	1.12	16
Bryum argenteum	0.62	25.0	3.0	1.32	13
Rhodobryum giganteum	1.50	51.5	8.5	1.52	13
Mnium coriaceum	1.50	41.3	10.8	1.25	13
Rhizogonium spiniforme	1.42	36.0	6.1	0.92	16
Philonotis anisoclada	1.24	31.0	2.5	1.65	21
Hypnodon perpusillus	0.83	2.3	1.1	0.45	20
Schlotheimia grevilleana	0.87	8.5	2.1	0.92	17

TABLE III (Contd.)

Name of moss	Length of foot in mm	Length of seta in mm	Length of capsule in mm	Breadth of capsule in mm	Diameter of spores in / μ
1	2	3	4	5	6
Papillaria crocea	0.79	5.5	2.4	1.12	16
Rhegmatodon orthostegius	0.91	7.0	2.1	0.92	20
Thuidium tamariscellum	0.70	17.0	3.2	0.85	13
Pleuropus nilghiriense	0.91	9.0	2.1	0.52	16
Rhynchostegium javanicum	0.83	19 0	4.1	0.80	9
Erythrodontium julaceum	0.54	19.5	1.6	1.00	20
Sematophyllum subhumile	0.66	11.0	1.6	0.45	10
Ctenidium lychnites	1.07	26.5	5.2	1.32	12
Atrichum aculeatum	1.70	39.5	6.8	1.45	16
Pogonatum microstomum	1.66	67.0	5.3	1.92	13
Pogonatum neesii	1.49	38 0	4.3	1.75	10

It may be seen from a perusal of Table-III that there appears to be no correlation between the size of the capsule and the diameter of the spores. Nor does it appear that there exists any relation between the length of the seta and the length of the capsule. But when length of the foot and the length of the capsule are taken into consideration there is a corresponding increase in the length of the foot *pari-passu* with the increase in the length of the capsule.

It was observed that the seta is short in the following mosses which grow on the bark and branches of trees and on bare rocks:

Hypnodon perpusillus
Leucobryum neilgherrense
Pleuropus nilghiriense
Papillaria crocea
Schlotheimia grevilleana

This is in confirmity with the observation of Goebel (1905).

The capsule

The columella in the capsule of the mosses studied is prolonged up-to the peristomial region. The wall of the capsule in the region of the apophysis is provided with stomata in some species. It has been reported by Haberlandt (1895) that the stomata are confined to the sporogonium where they often occur in large numbers on the apophysis which is the principal organ of photosynthesis and to a small extent on the capsule wall where

it is green He has sketched the stomata of six species of mosses and also stated that a single capsule of *Polytrichum* may bear three different types of stomata namely (1) two celled stomata; (2) one celled stomata with fused guard cells and (3) four-celled stomata in which each of the two primary guard cells is divided into two by a median transverse wall. Of the three kinds, the second type was not observed in this study. Campbell (1930), Ruhland (1924), and Grout (1924) have reproduced the illustrations of Haberlandt (1895). Van Der Wijk (1932) has reported the presence of stomata in *Orthotrichum*. Though Berkeley (1863) has stated that "stomata are not uncommon on the surface of the sporongia* in which case they resemble very closely those of Phaenarogams," they are not found on all the capsules in this study. Out of the 34 capsules, the stomata were observed only in the following 8 species:

1. *Trematodon ceylonensis* (Fig. 18)
2. *Barbula indica* (Figs. 75 & 76)
3. *Funaria hygrometrica* (Fig. 420)
4. *Funaria submarginata* (Fig. 121)
5. *Pohlia flexuosa* (Fig. 421)
6. *Hypnodon perpusillus*
7. *Rhegmatodon orthostegius* (Fig. 272)
8. *Rhynchostegium javanicum*

In all cases, the stomata are made up of two guard cells but the number of subsidiary cells is variable: In

* This term "sporangia" has been used by Berkeley (1863) obviously for "sporogonia."

Trematodon ceylonensis the cells of capsular wall are much oval oblong or polygonal and ovoid resembling the cells of the leaf A few stomata occurring in the lower surface of the apophysis in *Barbula indica* are provided with four guard calls (Fig. 76.)

The frequency of the stomata was calculated by taking a unit area of one hundred micrometer squares of the Netz micrometer eye-piece. The stomatal indices of the 8 species have been calculated (*Table* IV). Stomatal index according to Salisbury quoted by Trease (1945) is an expression of the percentage proportion of the ultimate divisions of the dermatogen of the capsule which have been converted into stomata. The formula for stomatal index is $I = \frac{S}{E+S}$ where S is the number of stomata per unit area and E, the number of epidermal cells in the same area.

TABLE-IV

Name of the moss	No. of cells per unit area (E)	No. of stomata per (same) unit area (S)	Stomatal index (I) $I = \frac{S}{E+S} \times 100$	
1	2	3	4	5
Trematodon ceylonensis	36	2	$\frac{2}{36+2} \times 100 =$	5.26
	35	2	$\frac{2}{35+2} \times 100 =$	5.32
	37	2	$\frac{2}{37+2} \times 100 =$	5.13
	36	2	$\frac{2}{36+2} \times 100 =$	5.26
	35	2	$\frac{2}{35+2} \times 100 =$	5.32
	38	2	$\frac{2}{38+2} \times 100 =$	5.00
			Average	5.21

TABLE-IV (Contd.)

1	2	3	4	5
Barbula indica	84	2	$\frac{2}{84+2} \times 100$	$= 2.32$
	85	2	$\frac{2}{85+2} \times 100$	$= 2.29$
	84	2	$\frac{2}{84+2} \times 100$	$= 2.32$
	82	2	$\frac{2}{82+2}$ 100	$= 2.38$
	80	2	$\frac{2}{80+2} \times 100$	$= 2.43$
	86	2	$\frac{2}{86+2}$ 100	$= 2.26$
			Average	2.33

TABLE - IV (Contd.)

1	2	3	4	5
Funaria hygrometrica	112	5	$\frac{5}{112 \div 5} \times 100 =$	4.33
	114	5	$\frac{5}{114+5} \times 100 =$	4.20
	110	5	$\frac{5}{110+5} \times 100 =$	4.34
	112	5	$\frac{5}{112+5} \times 100 =$	4.33
	110	5	$\frac{5}{110+5} \times 100 =$	4.34
	111	5	$\frac{5}{111+5} \times 100 =$	4.31
			Average	4.30

TABLE IV (Contd.)

1	2	3	4	5
Funaria submarginata	96	3	$\frac{3}{96+3} \times 100 =$	3.03
	97	3	$\frac{3}{97+3} \times 100 =$	3.00
	95	3	$\frac{3}{95+3} \times 100 =$	3.06
	97	3	$\frac{3}{97+3} \times 100 =$	3.00
	96	3	$\frac{3}{96+3} \times 100 =$	3.03
	94	3	$\frac{3}{94+3} \times 100 =$	3.09
			Average	3.04

TABLE - IV (Contd.)

1	2	3	4	5
Pohlia flexuosa	62	3	$\frac{3}{62+3} \times 100 =$	4.61
	60	3	$\frac{3}{60+3} \times 100 =$	4.76
	62	3	$\frac{3}{62+3} \times 100 =$	4.61
	63	3	$\frac{3}{63+3} \times 100 =$	4.54
	61	3	$\frac{3}{61+3} \times 100 =$	4.68
	63	3	$\frac{3}{63+3} \times 100 =$	4.54
			Average	4.62

TABLE-IV (Contd.)

1	2	3	4	5
Hypnodon perpusillus	60	2	$\frac{2}{60+2} \times 100 =$	3.23
	62	2	$\frac{2}{62+2} \times 100 =$	3.12
	63	2	$\frac{2}{63+2} \times 100 =$	3.07
	60	2	$\frac{2}{60+2} \times 100 =$	3.23
	58	2	$\frac{2}{58+2} \times 100 =$	3.33
	59	2	$\frac{2}{59+2} \times 100 =$	3.27
			Average	3.20

TABLE - IV (Contd.)

1	2	3	4	5
Rhegmatodon orthostegius	78	3	$\frac{3}{78+3} \times 100$	= 3.70
	77	3	$\frac{3}{77+3} \times 100$	= 3.75
	80	3	$\frac{3}{80+3} \times 100$	= 3.61
	78	3	$\frac{3}{78+3} \times 100$	= 3.70
	79	3	$\frac{3}{79+3} \times 100$	= 3.65
	77	3	$\frac{3}{77+3} \times 100$	= 3.75
			Average	3.69

TABLE-IV (Contd.)

1	2	3	4	5
Rhynchostegium javanicum	104	4	$\frac{4}{104+4} \times 100$	= 3.75
	102	4	$\frac{4}{102+4} \times 100$	= 3.77
	106	4	$\frac{4}{106+4} \times 100$	= 3.63
	102	4	$\frac{4}{102+4}$ 100	= 3.77
	105	4	$\frac{4}{105+4} \times 100$	= 3.66
	104	4	$\frac{4}{104+4} \times 100$	= 3.75
			Average	**3.72**

It may be seen that the stomatal indices of different species of mosses are specific as they are in the angiosperms (Trease, 1945), (Rangaswamy, 1959).

Further, measurements of the length and breadth of the stomata were made. An average of six readings in each case has been taken and tabulated as below:

TABLE-V

Name of the Mosses	No. of subsidiary cells per stoma	Length of the stoma (L) in μ	Breadth of the stoma (B) in μ	L/B Ratio
Trematodon ceylonensis	8	66	55	1.2
Barbula indica	10	33	27	1.2
Funaria hygrometrica	13	33	27	1.2
Funaria submarginata	10	55	44	1.2
Pohlia flexuosa	10	44	36	1.2
Hypnodon perpusillus	8	55	44	1.2
Rhegmatodon orthostegius	9	55	44	1.2
Rhynchostegium javanicum	10	49	39	1.2

It may be seen, therefore, that the length and breadth ratio of the stomata of the mosses seems to be uniformly similar.

The operculum

The opercula of the capsules were drawn separately (*Plate Nos.* XXII & XXIII) to gain a comparative idea of their shape and size. They have been classified into four groups as under;

1. Convex as in *Funaria hygrometrica* (Fig. 368)
2. Cupula shaped as in *Anomobryum subniditum* (Fig. 372)
3. Short beaked as in *Thuidium tamariscellum* (Fig. 380)
4. Long beaked as in *Rhynchostegium javanicum* (Fig. 381)

These groupings are in accord with the classification erected by Dunham (1951) for the opercula of the mosses of Northeastern United States.

The operculum of *Funaria hygrometrica* is slightly convex and cells are arranged in concentric rings (Fig. 369). It may persist even after maturity of the capsule though in most cases they fall off when the sporogonium ripens. There seems to be no correlation between the length of the capsule and the length of the operculum.

The peristome

The peristome of the mosses is considered to be of very great significance in the identification of the

mosses. The description of the peristome in this treatise is in conformity with the findings of Dixon (1914), Cardot (1922), Conard (1954) and Watson (1954). The peristome in the haplolepideae is made up of one ring of teeth. Each tooth is composed of fused walls of two adjacent circles of cells. As the outer cell-wall extends the entire width of the tooth, the outer surface appears to have horizontal partitions. As the inner side of the tooth is derived from two boundaries, the surface shows a longitudinal line marking the boundaries of these cells. The outer surface of the peristome is termed as exostome and the inner endostome. The peristomial teeth of this group of mosses are often forked above as in *Fissidens schimidii* (Fig. 6).

The peristome is present in two rings in the diplolepideae. The inner peristome is more delicate and fragile than the outer and is usually lighter in colour as shown in *Pohlia flexuosa* (Fig. 127). The structure of the peristome teeth of this group of mosses is just the reverse of those of the haplolepideae. They have a zigzag line on the outer face as seen in *Rhizogonium spiniforme* (Fig. 166). The peristome is lacking in some mosses like *Funaria submarginata* (Fig. 120).

The colour of the peristome as seen in these mosses is generally yellow and reddish brown. Bright crimson colour as has been stated by Richards (1950) has not been met with so far.

The spore

The study of the spores in mosses was made for the first time by Schimper (1836) though superficially.

MacClymont (1955) has studied the morphology of the spores of a large number* of species in relation to their singificance in systematics. Although these South Indian mosses have been described years ago, there is no complete description of the spores. Hence detailed information regarding the spores of these species in a comparative manner is recorded in this work

The spores of 4 species were studied following the general acetolysis method of Ertdman (1952). The rest of the spores could not be studied in the same manner for want of adequate quantity of spore materials. So, temporary mounting of the spores in the safranin mixture, already referred to, was done. As it stains the spores suitably, observations and measurements could be made satisfactorily. Some spores were simply mounted in the dry condition. The camera lucida diagrams of the spores are found in Plate No. XXIV (Figs. 386 416). As recorded already in the chapter on morphological observations and in Table - III, the diameter of the spores varies from 9μ to 27μ, the smallest being observed in *Hyophila involuta* and the largest in *Funaria submarginata*.

It is interesting to note that the smallest moss in this study viz. *Hypnodon perpusillus* produces very large spores. Most of them were found to be spherical in shape. The colour of the spores in general, is brown. The sculpturing and the thickness of the Coat varies differently in different species.

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* 653 species.

In the present study of the sporophyte, the following observations may be noticed:

In the sporophytes of 34 species, 8 different forms of foot have been observed for the first time.

Measurements of the foot and capsule reveal that there is corresponding increase in length of the foot *pari-passu* with the increase in length of the capsule.

Though the nature of looping of the seta appears to have doubtful bearing on the stucrture of the peristome corresponding to the need for the regulation of spore dispersal their correlation is possible.

Stomata were observed in 8 species. The stomatal index of each one of these mosses, appears to be specific. The L/B ratio of the stomata is a constant factor.

The opercula are classified under 4 groups conforming to the classifications of Dunham (1951).

The spores have been studied in detail and in a comparative manner.

Vegetative reproduction and regeneration:

The vegetative reproduction in mosses is such a common phenomenon that Professor Goebel (1905) has expressed the opinion "almost every living cell of a moss can grow out into protonema and may produce gemmae of different kinds". The most important contributions have been made by Braithwaite (1395), Sainsbury (1935, 1938, 1952) and Correns (1899). So far as Indian mosses are concerned, Singh (1930) has contributed that the bulbils and gemmae are found in two species of mosses from

Mussoorie. Regeneration in mosses has been worked out by Meyer (1940), Narayanaswamy & Lal (1957), Kachroo (1954), Chopra & Sharma (1956) and Banerji & Sen (1957).

There seems to be no work on the South Indian mosses in this line. Vegetative reproduction and natural regeneration have been observed in several species of mosses as indicated below:

Bulbils and leafy buds were found in the leaf axils of *Campylopus nodiflorus*, *Brothera leana* (Fig. 417) and *Rhynchostegium javanicum* (Fig. 419). In these mosses the leafy buds possess 5 to 6 leaves. The leaves are all united together forming a bud from the base of which number of rhizoids arise. These buds get detached from the plant and under favourable conditions grow independently.

Multicellular club-shaped gemmae have been found in the axils of the leaves of *Barbula indica* (Fig 73), *Bryum argenteum* and *Brachymenium exile* (Fig. 418). The gemmae of *Barbula indica* are found in clusters of 3 to 6 in the axils of apical leaves. In the axil, there is a small fleshy knob-like receptacle to which the gemmae are attached. They are in the form of club-shaped multicellular structures. To start with they are green in colour but later they become brownish. The gemmae in *Bryum argenteum* are also club-shaped but the head is narrower. They are found (6 to 10) in the axils of leaf. They resemble the brood bodies noticed in *Tortula papillosa* by Van Der Wijk (1932). The gemmae of *Brachymenium exile* exactly resemble those of *Bryum hemisphaericarpum* reported by Singh (1930). They are

also multicellular club-shaped bodies the larger head of which resembling the mandibles of insects.

Regeneration of mosses by the formation of rhizoids from detached and attached leaves has been found in *Leucobryum neilgherrense*. The rhizoids are formed from the apex of the leaf (Photomicrograph Fig. 564) and from the margin of the leaf (Photomicrograph Fig. 562) in this plant. Production of rhizoids from the base of the leaf was noticed in *Taxiphyllum taxirameum* (Photomicrograph Fig. 558) and in *Schlotheimia grevilleana*, *Sematophyllum subhumile* and *Pterobryopsis orientalis*. Profusely branched rhizoids were found to arise even from the young regions of the axis of *Leucobryum neilgherrense* and *Aerobryopsis longissima*.

Regeneration was also noticed by the formation of special asexual reproductive bodies in the form of triradiate or cross-like structures named as "deciduous rhizoprotonemata" by Grout (1947). These bodies are formed when the young plants of *Barbula indica* are kept growing in petri-dishes on wet filter paper. After 3 to 4 days protonematal outgrowths arising from any part of plant are ending into "rhizoprotonemata". They are green in colour from the first appearance. Actual developmental studies were not made. It is reported that these bodies are formed when the plants of *Barbula gregaria* were treated by 2, 4–D (Narayanasamy & Lal, 1957). But no such herbicide was used in the present investigation.

Anatomical Observations

Anatomy of the mosses in general has been worked out by Lorch (1931). Van Der Wijk (1932) has given an account of the morphology and anatomy of the mosses. Ruhland (1924) and Brotherus (1924) have left some information regarding the anatomy of the mosses. Tansley and Chick (1911) while describing the conducting system in *Polytrichaceae*, have referred to the contribution of Haberlandt (1895) to Moss Anatomy in glowing terms However, the anatomical studies of the South Indian mosses have never before been attempted by any author.

Transverse sections of axis of 53 species of mosses and longitudinal sections of some of them have been investigated and the observations thereof, have been presented in this chapter. The diameter of the axis varies very much in different mosses. The structure of the moss axis in its cross section is not the same in all cases. The different parts of the tissue have been described with different terminology by different authors from time to time. The present investigation deals with the axis.

1) **Description :**

1.* *Fissidens schimidii* C. M. Transverse section of axis ovate in outline $142\mu \times 90\mu$. Epidermis thick-walled not distinguishable form outer cortex; both forming hypodermal rind of 18μ to 20μ thickness; cells very small and cell walls heavily thickened. Inner cortex composed of two layers of very large and thinw-alled cells. Central strand made up of pith; cells very small and thin-walled (Fig. 458).

2. *Ditrichum amoenum* (Thw. & mitt.) Par. Transverse section of axis bluntly triangular in outline, 120μ in diameter. Epidermis not differentiated from outer cortex forming hypodermal rind of 15μ to 20μ thickness. Cells uniform and walls heavily thickened. Inner cortex with much thick-walled cells of 3 to 4 laye s innermost layer of cortex with slightly larger cells. Central strand made up of pith, cells very small and thin-walled (Fig. 459).

4. *Campylopus nodiflorus* (C. M.) Jaeg. Transverse section of axis ovate in outline. Epidermis not distinguishable from the outer cortex; both layers forming rind of 22μ thickness. Cells heavilty thickened, cell lumen elongated. Inner cortex of 4 to 5 layers of not very much thickened cell walls. Central axis hollow (Fig. 463) in the older regions. Younger axis with central narrow pith of thin-walled cells, the outer cortex and epidermis remaining the same.

5. *Thysanomitrium depallieri* Card. Transverse section of axis slightly ovate in outline $198\mu \times 154\mu$.

* Number indicates the same serial number of mosses as referred to in the Morphological Observations.

Epidermis not distinguishable from outer cortex; both forming hypodermal rind of 20μ to 25μ thickness with heavily thickened cell walls. Inner cortex made up of 6 to 7 layers of polygonal cells gradually thickened outwards. Centre of the young axis with thin-walled pith cells; older regions with a hollow cavity (Fig. 464).

6. *Thysanomitrium lioneurum* (Ther. & Vard.) Broth. Transverse section of axis more or less round. Epidermis not distinguishable from outer cortex; cells heavily thickened. Inner cortex not differentiaed; cells large; thin-walled, but becoming thicker walled outwards. Central strand made up of pith in the young condition. Centre of older axis hollow forming a small cavity.

8. *Dicranodontium fragile* (Hook.) Broth. Transverse section of axis irregularly ovate 220μ $\times$ 195μ. Epidermis not discernible from outer cortex; both forming rind of 15μ thickness; cells heavily thick-walled. Inner cortex not differentiated; cells large and polygonal, thin-walled but gradually becoming thicker-walled out-wards. Central portion in older regions of axis hollow.

9. *Leucobryum neilgherrense* C. M. Transverse section of axis more or less roundish 160μ $\times$ 175μ, epidermis thick-walled. Rind conspicuous by absence. All cells beneath epidermis uniformly distributed without any differentiation of cortex or central strand. Cell-walls not much thickened (Fig. 432).

10. *Leucobryum scalare* C. M. Transverse section of axis more or less roundish 350μ to 360μ in diameter.

Epidermis thick-walled; outer cortex 3 to 4 layers of thick-walled cells forming rind. Entire tissue inside the rind made up of uniform and polygonal cells without any differentiation of cortex or central strand; cell-walls not much thickened. In older axis rind well laid. Epidermis not discernible. Inner tissue with uniformly thick-walled cells (Fig. 440).

12. *Barbula indica* (Schw.) Brid. Transverse section of axis roundish, 154μ in diameter. Epidermis not distinguishable from outercortex; both forming rind of 30μ thickness; cell walls heavily thickened. Inner cortex not differentiated; cells thin-walled. Central strand made up of pith of thin-walled cells.

16. *Hyophila validinervis* Card. and Vard. Transverse section of axis small ovate, 220μ to 260μ in outline. Epidermis not detectable from outer cortex; both forming rind of 88μ thickness; cells heavily thick-walled and elongated. Inner cortex not differentiated; cells uniformly polygonal, thin-walled but thick-walled in the outer layers. Centre hollowed into a cavity in the old axis (Fig. 465). In young axis centre made up of pith cells.

17. *Rhacomitrium javanicum* Bryol. Transverse section of axis roundish 220μ in diameter. Epidermis not distinguishable from outer cortex; both forming rind of 25μ thickness; cell walls heavily thickened. No differentiation of tissue inside rind, cells thick-walled, uniformly distributed.

18. *Funaria hygrometrica* Hedw. Transverse section of axis roundish 264μ in diameter. Epidermis thin-walled. Outer cortex 3 to 4 layers slightly thick-walled forming rind. Inside rind cells isodiametric, thin-walled uniformly distributed. In older axis epidermis and rind discernible but cell-walls thickened. Inner cortex thin-walled. Central strand made up of pith; cells very thin-walled and smaller.

19. *Funaria submarginata* Card. and Vard. Transverse section of axis small and roundish 100μ in diameter. Epidermis not distinguishable from outer cortex; both forming rind of 22μ thickness. Cell-walls very heavily thickened; cell lumen obliterated. Inside rind, axis hollowed (Fig. 456).

20. *Pohlia flexuosa*(Mitt.)Broth. Transverse section of axis slightly ovate 160μ × 144μ. Epidermis not distinguishable from outer cortical rind; cell-walls much thickened. Inner cortex with much thin-walled layers of cells. Central strand made up of pith; cells smaller and thin-walled.

25. *Rhodobryum giganteum*(Hook.)Par. Transverse section of axis roundish 880μ in diameter. Epidermis with thick-walled small cells, provided with epidermal hairs. Outer cortical rind made up of 4 to 5 layers of thick-walled cells. Inner cortex differentiated into 2 zones; the outer zone just beneath the rind made up of many layers of larger and thick-walled cells; the inner zone of inner cortex composed of 2 to 3 layers of much thick-walled smaller cells. The central strand in the form of

pith in younger axis; in older regions centre of the axis hollow (Fig. 467) forming a cavity.

26. *Mnium coriaceum* Griff. Transverse section of younger axis (Fig. 457) roundish 500μ in diameter. Epidermis not detectable from outer cortex; both forming rind of 42μ thickness made up of 3 to 4 layers of heavily thickened cell walls. Inner cortex not differentiated; 5 to 6 rows of thin-walled cells becoming thick-walled outwards. Central strand composed of collenchyma-like cells with angular thickening. In older axis central strand well formed with heavily thick-walled cells; innermost layer of inner cortex made up of larger cells (Fig. 470).

27. *Rhizogonium spiniforme* (L.) Bruch. Transverse section of axis irregularly pentagonal in outline 242μ $\times$ 262μ. Epidermis not distinguishable from outer cortex; both forming rind 25μ thickness with heavily thick-walled cells. Inner cortex not differentiated; cells thin-walled but gradually thick-walled outwards. Central strand consists of thin-walled small cells forming a pith.

28. *Bartramia madurensis* Dix. & Vard. Transverse section of axis irregular in shape 220μ $\times$ 262μ. Epidermis not distinguishable from outer cortex both forming rind of 45μ thickness; cells heavily thick-walled. Tissue inside rind not differentiated, made up of thick-walled cells (Fig. 442).

29. *Philonotis anisoclada* Card. and Vard. Transverse section of axis small and slightly roundish 220μ

$\times 200\mu$. Epidermis thick-walled; outer cortex of 2 layers of cells forming rind; cells narrow and thick-walled. Inner cortex extended to centre of axis; cells thick-walled. Centre of axis without strand or core but with a small cell surrounded by 4 to 5 thick-walled narrower cells (Figs. 449 and 450).

31. *Schlotheimia grevilleana* Mitt. Transverse section of axis ovate $262\mu \times 330\mu$ in diameter. Epidermis not distinguishable from outer cortex; both forming rind of 22μ thickness; cells heavily thickened but lignification slightly different. Safranin stain not deep red as in others but light; hence thickening stippled. Tissue inside rind not differentiated; cell walls heavily thickened (Fig. 441).

32. *Trachypus bicolor* Rein. & Hornsch. Transverse section of axis ovately flattened $220\mu \times 330\mu$. Epidermis not distinguishable from outer cortex; both forming 25μ thick rind; cell walls very heavily thickened. Tissue inside rind made up of several layers of thick-walled narrow cells surrounding a very small narrow cell (Figs. 451 & 452).

33 *Trachypus humilis* Lindb. Var *humilis* Zanten. Transverse section of axis small. Epidermis not distinguishable from outer cortex; both forming rind of 22μ thickness; cell walls heavily thickened. Inner tissue of axis composed of thick- walled large cells extending up-to centre of axis, possessing 10 to 12 layers of thick-walled narrow cells surrounding a single central cell.

34. *Trachypodopsis serrulata* (Beav.) Fleisch. Var. *crispatula* (Hook.) Zanten. Transverse section of axis

fairly large and irregularly rounding 396μ × 462μ. Epidermis not distinguishable from outer cortex; both forming 45μ thick rind; cell walls very heavily thickened. Inside rind several layers of large cells uniformly thick-walled. Centre of axis consisting of a rind of narrow 5 to 6 thick-walled cells enclosing two slightly elongated cells.

35. *Myurium warburgii* (C. M.) Fleisch. Transverse section of axis small ovate in outline 155μ × 220μ. Epidermis not distinguishable from outer cortex; both forming rind of 30μ thickness; cell walls heavily thickened. Tissue inside rind not differentiated; cell-walls much thickened and in several concentric layers (Fig. 443).

36. *Pterobryopsis orientalis* (C. M.) Fleisch. Transverse section of axis ovate in outline 420μ × 484μ. Epidermis and outer cortex forming rind of 25μ thickness; cell walls so heavily thickened that cell lumen not visible. Inner cortex differentiated into outer zone and inner zone; outer zone consisting of 6–7 layers of thick-walled cells; inner zone made up of 10 to 12 layers of slightly thick-walled cells. Central strand organised with a group of very narrow and much thick-walled cells (Fig. 472).

37. *Papillaria crocea* (Hamp.) Jaeg. Axis flattened; transverse section of axis ovate in outline 220μ × 310μ Epidermis not distinguishable from outer crotex; both forming rind of 42μ thickness ; cellwalls very heavily thickened Inner undifferentiated tissue composed of uniformly thick-walled cells (Fig. 444).

38. *Aerobryopsis longissima* (Doz. & Molk.) Fleisch. Axis flattened; transverse section narrowly ovate $528\mu \times 296\mu$. Epidermis not distinguishable from outer cortex; both forming rind of 33μ thickness. Tissue inside rind not differentiated; cells uniformly thick walled and distributed around a single small cell situated in the centre.

39. *Barbella tenax* (C. M.) Broth. Axis flattened; transverse section irregularly ovate $126\mu \times 180\mu$ Epidermis not distinguishable from outer cortex; both forming rind of 20μ thickness; cell walls heavily thickened; cell lumen scarcely seen. Inside rind, axis hollowed out into large cavity (Fig. 468).

40. *Barbella determessi* (Rein & Card.) Fleisch. Transverse section of axis irregularly roundish 176μ in diameter. Epidermis and outer cortex forming rind of 25μ thickness; cell-walls heavily thickened. Cells inside rind much thick-walled. Central most cell slightly larger surrounded by a ring of 7 - 8 smaller cells.

41. *Barbella pendula* (Sull.) Fleisch. Transverse section of axis ovate in outline $176\mu \times 143\mu$. Epidermis and outer cortex forming rind of 25μ thickness; cell walls very heavily thickened. Tissue inside rind uniformly thick-walled; cell lumen narrow almost spindle shaped (Fig. 445).

42. *Floribundaria floribunda* (Doz. and Molk.) Fleisch. Transverse section of axis irregularly roundish 242μ in diameter. Single layer of epidermis distinguishable from outer cortex of three layers of

narrow thick-walled cells forming rind of 22μ thickness. Tissue inside rind containing uniformly thin-walled cells excepting the central region of 6 - 7 smaller cells.

43. *Meteoriopsis squarrosa* (Hook) Fleisch. Axis flattened; transverse section of axis ovate 396μ × 220μ (Fig. 461). Epidermis not distinguishable from outer cortex both forming rind of 20μ thickness. Inner cortex differentiated into three zones, outer zone of thick-walled narrow cells, mid zone of larger cells and inner zone of thick-walled cells with narrow lumen. Central axis compressed*. Lignification not very much.

44. *Meteoriopsis reclinata* (C. M.) Fleisch. Transverse section of axis ovate in outline 440μ × 262μ. Epidermis not distinguishable from outer cortex; both forming rind of 30μ to 40μ thickness; cell walls heavily thickened. Inner cortex not differentiated; cells thin-walled but gradually becoming thick-walled outwards. Central strand organised + by pith-like thin-walled smaller cells (Fig. 460).

45. *Homaliodendron exiguum* (Bryol Jav.) Fleisch. Transverse section of axis ovate in outline 242 × 176μ. One layer of cells of epidermis and 3 - 4 layers of outer cortex distinguishable; both forming rind of 33μ thickness; cell walls very much thickened. Tissue inside rind without any differentiation and uniformly thin-walle.

* Similar feature recorded by Lorch (1931) in the Transverse section of seta of *Cinclidium stygium Schw.*
+ Similar structure observed by Lorch (1931) in the axis of *Mninm cinclidioides* Hueb.

46. *Homaliodendron flabellatum (*Dix. Sm.*)* Fleisch. Transverse section of axis ovate in outline 506μ × 396μ. Epidermis not distinguishable from 6 - 7 layers of outer cortex both forming rind of 55μ thickness; branch organised. Tissue inside rind not differentiated; cells isodiametric and uniformly thick-walled (Figs. 446 & 447).

47. *Distichophyllum succulentum* (Mitt.) Broth. Transverse section of axis irregularly roundish in outline 220μ in diameter. Epidermis not distinguishable from outer cortex; both forming heavily thickwalled rind of 30μ thickness. Inner cortex also thick-walled but differentiaied by safranin, not deeply red as outer cortex, hence stippled (Fig. 434). Beneath inner cortex central starnd of uniformly thin-walled and sinuated cells forming pith-like tissue.

48. *Hookeria acutifolia* Hook. Transverse section of axis ovate 272μ × 392μ. Epidermis made up of single layer of thick-walled cells ; lumen smaller and distinct from the lumen of the cells inside. No differentiation of cortex ; no rind ; no strand. Tissue of axis below epidermis consists of isodiametric pentagonal cells. Cell-wall not much thickened, turns light red by safranin (Figs. 430 & 431).

49. *Hypopterygium tenellum* Lac. = *H. ceylanicum* Mitt. Transverse section of axis roundish 308μ in diameter. Epidermis and cortex distinguishable. Cell walls very much thickened but turning light red by phloroglucin and safranin. Cortex large not differentiated. Central strand made up of pith of uniform and isodiametric very thin-walled cells (Fig. 433).

50. *Rhegmatodon orthostegius* Mont. Transverse section of axis irregularly ovate 396μ × 286μ. Epidermis not distinguishable from outer cortex; both form rind of 25μ thickness; cell walls heavily thickened. Tissue inside rind not differentiated uniformly thick-walled.

51. *Herpetineurum toccoae* (Sull. & Lesq.) Card. Transverse section of axis irregularly ovate 374μ × 310μ. Epidermis and outer cortex not distinguishable. Both form rind of 44μ thickness ; cell walls heavily thickened. Inner cortex not differentiated ; cells uniformly thick-walled. Central strand present in the form of pith of very thin walled cells.

52. *Thuidium tamariscellum* (C. M.) Bryol. Jav. Transverse section of primary axis roundish 440μ in diameter. Epidermis not distinguishable from outer cortex ; both forming rind of 33μ thickness. Tissue inside rind not differentiated ; cells uniformly thin-walled

53. *Pleuropus nilghiriense* (Mont,) Toyama. Transverse section of axis slightly ovate 330μ × 310μ. Epidermis not distinguishable from outer cortex ; both forming rind of 40μ thickness ; cells heavily thickened; Inner cortex differentiated into inner and outer zones; cells of the inner zone very thin-walled and cells of the outer zone uniform, thick-walled. Central axis hollowed into a narrow cavity.

54. *Rhynchostegium javanicum* (Bel.) Besch. Axis flattened. Transverse section of axis 418μ × 286μ ovate

(Fig. 462). Epidermis not distinguishable from outer cortex; both forming rind of 18μ to 20μ thickness. Tissue inside rind composed of uniformly thin-walled cells. Cells of central axis compressed forming·long streak.*

55. *Erythrodontium julaceum* (Hook.) Par. Transverse section of axis irregularly ovate 286μ × 242μ. Epidermis not distinguishable from outer cortex; both forming rind of 20μ to 40μ thickness; cell walls heavily thickened; cell-lumen very small. Cells inside rind uniformly thick-walled; cell-lumen larger except in central axis; 3 to 4 cells with narrow lumen found in the centre (Fig. 453).

56. *Foreauella indica* Dix. & Vard. Transverse section of axis irregularly ovate 264μ × 176μ in diameter. Epidermis not distinguishable from outer cortex; both forming rind of 45μ thickness; cell walls heavily thickened. Tissue inside rind composed of uniformly thick-walled cells. Centrally-placed small single cell around a ring of seven radiating cells observable (Fig. 448).

57. *Sematophyllum subhumile* (C.M.) Fleisch. Axis very narrow; transverse section very irregular in outline 110μ × 70μ. Epidermis not distinguishable from oute cortex; both forming rind of 12μ thickness; cell walls heavily thickened. Tissue inside rind composed of thick-walled cells; inner cortical cells very small (Fig. 439).

58 *Warburgiella leptorrhynchoides* (Mont.) Fleisch. Axis flattened; transverse section irregularly ovate

*Similar feature recorded by Lorch (1931) in the transverse section of seta of *Cinclidium stygium* Schw.

$154\mu \times 88\mu$. Epidermis not distinguishable from outer cortex; both forming rind of 10μ thickness. Tissue inside rind not differentiated; cells uniformly thin-walled (Fig, 438).

59. *Hypnum cupressiforme* Hedw. Transverse section of axis irregularly ovate $176\mu \times 132\mu$. Epidermis not distinguishable from outer cortex; both forming rind of 12μ thickness; cell walls heavily thickened; inner cortex differentiated with peripheral thick-walled cells and central thin-walled cells. Very small narrow lumen in the central most region of axis with 7 radially elongated cells observable (Fig. 456).

60. *Taxiphyllum taxirameum* (Mitt.) Fleisch. Transverse section of axis almost roundish, 188μ in diameter. Epidermis not distinguishable from outer cortex; both forming rind of 15μ thickness; cell walls heavily thickened; tissue inside rind not differentiated, cells thin-walled. Centrally placed single cell surrounded by a ring of 7 - 8 elongated and radiating cells as in (Fig. 456).

61. *Ctenidium lychnites* (Mitt.) Broth. Axis flattened; transverse section irregularly ovate $264\mu \times 154\mu$. Epidermis not distinguishable from outer cortex; both forming rind of 15μ thickness; cells inside rind thin-walled but peripheral layers slightly thick-walled. Centrally placed single narrrow very small cell possessing ring of 5 - 6 radiating and elongated cells (Fig. 455).

62. *Atrichum aculeatum* Card. & Vard. Transverse section of axis almost roundish 264μ in diameter.

Epidermis not distinguishable from outer cortex; both forming rind of 10μ to 15μ thickness; cell walls heavily thickened, cell lumen very small. Inner cortex differentiated into three zones; outer zone composed of two incomplete rows of thick-walled cells: mid zone made up of 3 5 rows of thick-walled calls of smaller size; inner zone composed of two rows of thin-walled cells with angular thickening. Inside inner zone of inner cortex central strand of thick-walled cells found in older axis (Fig. 474) But in younger axis central strand formed by very thin walled pith cells (Fig 473).

63. *Pogonatum microstomum* (R. Br) Brid. Transverse section of axis very large, roundish 440μ in diameter: Epidermis not distinguishable from outer cortex; both forming rind of 50μ thickness; cell walls very heavily thickened. Inner cortex differentiated into two zones: outer zone beneath the rind made up of several layers of highly thick-walled smaller cells; inner zone composed of several layers of larger and thin-walled collenchyma-like cells. Central core with angular projections forming the central strand composed of very heavily thickened very small and narrow cells.

64. *Pogonatum neesii* (C.M.) Mitt. Transverse section of axis very irregular in outline 264μ in diameter. Epidermis not distinguishable from outer cortex; both forming rind of 45μ thickness; cell walls so heavily thickened that cell-lumen hardly seen. Inner cortex differentiated into outer zone and inner zone;* outer zone made up of

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* Similar structure of the axis has been reported by Frye and Ferguson (1943) in *Pogonatum liebmannianum* C. Muell. but without angular projections of the central strand.

6-7 layers of very much thick-walled cells, cell lumen very narrow; inner zone composed of 4 or 5 concentric layers of collenchyma-like cells. Central axis made up of strand with 5 or 6 angular projections; cells small walls very much thickened, cell lumina of stra· d veıy narrow in peripheral 5-6 layers and slightly larger in the central region (Fig. 475).

2) Rest lts :

Transverse sections of the axes of 53 species of mosses were taken The axes of the rest of the 11 species such as: *Trematodon ceylonensis*, *Brothera leana*, *Tortula muralis*, *Trichostomum cylindricum*, *Weisia macrospora*, *Hyophila involuta*, *Brachymenium exile*, *Brachymenium leptostomoides*, *Anomobryum subniditum*, *Bryum argenteum*, and *Hypnodon perpusillus* could not be sectioned. The structuıe of the transverse section of the axis may be differentiated into three regions: the epidermis, the cortex and the central strand. The outer most is the epidermis. The cortex is often very much thickened in the outer portion forming a rind. The cells of the rind are very heavily. thick-walled. The inner cortex may or may not be differentiated. Inside the cortex, there is a central strand or core of the axis. This is made up of either thin-walled or thick-walled cells.

There is a good deal of variation in the structure of the axis. They may be outlined as under:-

1. The epidermis and the rind may not be distinguishable but may be uniform (Fig. 431).

2. The rind may be conspicuous by its absence (Fig. 433).

3. The cortex may not be differentiated (Fig. 433) and cell-walls of pith be sinuate (Fig. 435).

4. There may absolutely be no differentiation of the tissue beneath the rind (Fig. 436). The cells may either be thin-walled (Fig. 438) or thick-walled (Fig. 440).

5. The differentiation of the tissue inside the rind may be initiated by the presence of a centrally situated small cell with an outer ring of radiating cells (Figs. 449 to 456).

6. Where a central strand is present it may be composed of thin-walled pith cells (Fig. 457) in the younger regions of the axis. In the older regions the centre of the axis may be made up of very heavily thick-walled cells forming this strand. The strand is differentiated in *Pogonatum microstomum* and *Pogonatum neesii*.

7. Instead of a pith in the centre a hollow cavity may be present (Figs. 463—469).

The anatomical features so observed have afforded a critical basis for the classification of the mosses.

Longitudinal sections of the axes of the following mosses were taken:-

Pogonatum microstomum
Pogonatum neesii
Rhacomitrium javanicum
Rhizogonium spiniforme
Homaliodendron flabellatum
Thuidium tamariscellum

It has been found that the cells of the epidermis and those of the rind are scarcely discernible as the thickening of the cell-wall is often enormous. The cells of the inner cortex are elongated and the cross walls are oblique. They are not so much thickened as the cells of the rind. The cell wall of the central strand are also equally thickened and they take up deep Safranin stain. The double staining process with Safranin and Fast Green or Haematoxylin and Eosin differentiates the central strand very clearly from the outer layer of large cells.

The cells of the axis of certain mosses were separated with the help of Schultze's maceration fluid and stained suitably with Phloroglucin. It is found that lignification has taken place in the cells of the rind and of the central strand much more than in other regions.

The anatomy of the leaves of a few mosses was studied. The transverse section of the leaf of *Fissidens schimidii* reveals the presence of dorsal lamella as an outgrowth (Fig. 5).

The cross sections of the leaf of *Leucobryum scalare* and *Leucobryum neilgherrense* (Figs. 51 & 58) have been found to possess multicellular structure. The former shows a row of collenchyma-like corner thickened cells in the centre. Similar observations were made by Brotherus (1925) in *Leucobryum sanctum*, and by Van Der Wijk (1932) and Conard (1956) in *Leucobroum glaucum*. The cross section of the leaves of the two species of *Pogonatum* is interesting. It resembles the transverse section of the thallus of Marchantiales. There are

longitudinal rows of cells arranged one above the other containing chloroplasts. They form the lamellae. The uppermost rows of cells in *Pogonatum neesii* are different from those of *Pogonatum microstomum*. In all other cases the leaves are made up of single row of cells. In the region of the mid rib thick walled cells in two or three rows are found.

It is interesting to note that the structure of the axis in the young region is considerably different from that of the axis in the older regions. For example the axis of *Funaria hygrometrica* according to Campbell (1930) possesses a central cylinder of thin-walled cells when young which gradually gets converted into a thick-walled central strand at maturity. This may be true of some mosses as *Polytrichum commune* (Tansley and Chick 1901); but not in all cases.

Lorch (1931) has sketched transverse section of the axis of *Campylopus polytrichoides* both in the young and old conditions. The former shows a well defined pith made up of thin-walled parenchyma-like cells and the latter has a hollow cavity in the centre. This feature is exhibited in some of the Nilgiri mosses such as :-

Campylopus nodiflorus (Fig. 463)
Thysanomitrium depallieri (Fig. 464)
Thysanomitrium lioneurum
Dicranodotnium fragile
Hyophila validinervis (Fig 465)
Funaria submarginata (Fig 466)
Rhodobryum giganteum (Fig 467)

Barbella tenax (Fig. 468)
Pleuropus nilghiriense and
Entodon plicatus (Fig. 469.)

The second outstanding observation is the presence of a rind consisting of 4 to 7 rows of very much thick-walled cells in most cases. Lorch (1931) has drawn attention to this fact by showing the different patterns of thickening of the rind along with the epidemis. This rind is found to be formed and well-laid even in the young condition. It is conspicuous by its absence in a few cases such as *Distichophyllum succulentum* and *Hookeria acutifolia.* In these two species the epidermis can be clearly distinguished as being made up of barrel-shaped cells (Fig. 430). Brotherus (1924) has also observed this feature in *Sarconeurum glaciale* (Hook fil. et Wils.) Card. et Bryhn. and in *Hookeriopsis incurva* (Hook et Arev.) Broth.

In some moss axes, it has been noticed that just inside the rind, the entire central portion of the axis is made up of undifferentiated and uniformly thin-walled cells as in the following:

Leucobryum scalare (Fig. 440)
Rhacomitrium javanicum
Schlotheimia grevilleana (Young, Fig. 441.)
Schlotheimia grevilleana (Old, Fig. 442.)
Myurium warburgii (Fig. 443)
Papillaria crocea (Fig. 444)
Barbella pendula (Fig. 445)

Homaliodendron flabellatum (Fig. 446)
Rhegmatodon orthostegius and
Herpetineurum toccoae.

Lorch (1931) has observed a similar structure in the axis of *Pilotrichidium antillarum*. The following mosses possess yet another kind of central structure in the axis. Instead of the thin-walled or thick-walled cell distribution in the centre there occurs a centrally situated cell having a narrow or large lumen often surrounded by a ring of cells radiating outwards.

Philonotis anisoclada (Fig. 449)
Trachypus bicolor (Fig. 451)
Aerobryopsis longissima
Floribundaria floribunda
Erythrodontium julaceum (Fig. 454)
Hypnum cupressiforme (Fig. 456) and
Ctenidium lychnites (Fig. 455).

The central strand (Zenral-strang) which has been referred to by some authors as the central core of conducting strand is found in the two species of *Pogonatum* belonging to the *Polytrichaceae*. Though *Polytrichum* has not been so far found to grow in South India, its relatives,* viz. *Pogonatum microstomum* and *Pogonatum neesii*, are abundant in the South Indian

* The other available species *Pogonatum aloides*, *P. hexagonium*, *P. inflexum* and *P. junghuhnianum* were not included in this work due to difference of opinion in the specific determination.

Hill stations. It has been found that this genus exhibits almost the same structure as *Polytrichum*. The central strand is well developed. The strand possesses four to six angular projections abutting on the cortex. Outside this central strand there is a layer of comparatively thin-walled, sometimes large cells followed by a few layers of thin-walled cells lying beneath the rind (Figs. 474 & 475).

Having these facts in view the 53 species of mosses belonging to 26 families have been classified on the basis of the following principles :—

1. The presence or absence of the rind.
2. The differentiation of the tissue inside the rind or the same without differentiation.
3. The presence or absence of the central strand.
4. The differentiation of the central strand or the same without differentiation.
5. The presence of a pith or cavity in the centre.
6. The presence of a small cell in the centre of the axis surrounded by a ring of cells.

The detailed classification proposed in this treatise is presented in Table-VI.

TABLE VI

SYSTEM OF CLASSIFICATION OF THE MOSSES
PROPOSED HERE ON THE BASIS OF ANATOMICAL STRUCTURE *

- Bryales
  - With peripheral rind
    - With Central strand
      - Central strand differentiated
        - Polytrichaceae
      - Central strand not differentiated but present as pith
        - Fissidentaceae
        - Ditrichaceae
        - Mniaceae, Rhizogoniaceae
        - Meteoriaceae, Neckeraceae
    - Without central strand
      - Centre of axis differentiated
        - As hollow cavity
          - Brachytheciaceae
          - Dicranaceae, Pottiaceae
          - Funariaceae, Bryaceae
          - Meteoriaceae,
          - Entodontaceae
        - With a single central cell
          - Bartramiaceae
          - Trachypodaceae
          - Meteoriaceae
          - Entodontaceae, Hypnaceae
      - Centre of the axis not differentiated
        - Thick - walled cells uniformly distributed
          - Grimmiaceae
          - Orthotrichaceae
          - Trachypodaceae
          - Myuriaceae
          - Pterobryaceae
          - Neckeraceae, Leskeaceae
          - Thuidiaceae
          - Sematophyllaceae
        - Thin-walled cells uniformly distributed
          - Orthotrichaceae
          - Meteoriaceae
  - Without peripheral rind
    - Axis differentiated into pith
      - Hypopterygiaceae
    - Axis not differentiated into pith
      - Leucobryaceae
      - Hookeriaceae

* Very interesting! A. J. Sharp.

It may be observed further:

1. that the pith in the young axis has become the central strand in the following:

   Mnium coriaceum (Figs. 457 & 470)
   Artichum aculeatum (Figs. 473 & 474)

2. that the pith in the centre of the young axis has developed a hollow cavity in the following:

   Campylopus nodiflorus (Fig. 463)
   Thysanomitrium depallieri (Fig. 464)
   Hyophila validinervis (Fig. 465)
   Funaria submarginata(Fig. 466)
   Rhodobryum giganteum (Fig. 467)

3. that the uniformly thick walled cells in the centre of the young axis have developed a single central cell in the old axis in the following:

   Schlotheimia grevilleana (Fig. 441)
   Philonotis anisoclada (Figs. 449 & 450)

4. that the centrally situated single cell in the young axis has developed a hollow cavity in the following:

   Barbella tenax (Fig. 448)

Physiological Observations

Different aspects of physiology of mosses have been dealt with by several authors, most important among them being Haberlandt (1886), Lorch (1925), Goebel (1905), Oltmanns, (1884) Stelmach (1926) and Brilliant (1927). This wide and vast field has many facets but in this investigation a few experiments on certain aspects alone were under-taken. They are (1) on the effect of pH and hormones on the growth of moss plant ; (2) the production of rhizoids from the foot of the sporophyte of mosses; and (3) comparative studies in the osmotic concentration of the gametophytic nd sporophytic tissues of mosses.

There have been many limitations in the pursuit of this kind of study. Most of the experiments had to be conducted in the hill stations - the very home of the mosses. In many cases the sporophytes are not usually produced and when they are produced they are short-lived. As Garjeanne (1932) has pointed out, "a reliable method for cultivating the bryophytes on their natural substrata in the laboratory would however be of great value to the physiologist." As per the suggestion, certain experiments were carried on in the same manner in the University Laboratory. Some tufts of mosses with sufficient soil were uprooted and brought from the hills.

They were growing allright for sometime but in the long run they died even when they were enjoying normal conditions of life of the Hills.

The effect of pH on the growth of mosses:

Reference has already been made (P. 8) to the effect that the soil of the following mosses has been found to be acidic:

Name	pH
Fissidens schimidii	5.4 to 5.6
Ditrichum amoenum	5.2 to 5.4
Leucobryum neilgherrense	5.6 to 5.8
Barbula indica	6.2 to 6.4
Bartramia madurensis	4.5 to 4.6
Barbella pendula	6.0
Pogonatum neesii	5.6 to 5.8

These findings only confirm the observations of Olsen (1923) that "each species had a different optium pH, corresponding more or less with the pH of its natural habitat."

One of the mosses referred to above, *Barbula indica* grows well on the open terrace of the laboratory. The plants were treated with buffer solutions of different concentrations in the following manner.

The terrace is plastered with lime-mortar. This moss grows during winter in shade cast by the parapet wall. In selected plots, small bunds of 50 cm × 30 cm

were constructed. The plots were protected from sun and rain with thatches of palm leaves. Daily towards evening the plots were irrigated with equal quantity of buffer solutions of different concentrations of varying pH from 4.6 to 9. The experiments were carried on for fifteen days. The control plot of the same dimensions was irrigated with same quantity of distilled water. The initial height of the plants in all the plots was 5 mm. Observations were taken once in every five days. The results are tabulated as under.

TABLE-VII

1	2	3	4	5	6
Height of plant	pH 4.6	pH 6	pH 8	pH 9	Control
Fifth day	7 mm	6 mm	5.5 mm	showed signs of wilting	6 mm
Tenth day	9.5 mm	8 mm	showed signs of wilting	plants died	7.5 mm
Fifteenth day	12 mm	10 mm	Plants died	Plants died	9 mm

It may be seen that increase in pH (on acidic side) is directly proportional to the growth of the stem.

In the same manner growth hormones such as Indole Acetic Acid (I A A), Indole-Butyric Acid .(I B A), and 2,4-D were irrigated to investigate the nature of growth

of *Barbula indica* in a few other plots. The concentration of the hormones used was 1%. The control plot was irrigated with same quantity of distilled water. The observations are recorded in Table No. VIII.

TABLE-VIII

1	2	3	4	5
Height of Plant	I A A	I B A	2,4-D	Control
Fifth day	6 mm	6 mm	6 mm	6 mm
Tenth day	8 mm	9 mm	7.5 mm	7.5 mm
Fifteenth day	9.5 mm	10 5 mm	9 mm	9 mm
Twentieth day	12 mm	15.5 mm	12.5 mm	12 mm
Twenty-fifth day	13 mm	18 mm	16 mm	15 mm

It may be seen that I B A induces greater growth of the plants than the other hormones. Microscopic examination of the plants treated with 2,4-D reveals that the leaves upon the shoots were generally spaced farther apart though no appreciable increase in height could be noticed. This finding is in confirmation of the observations of Prior (1952). Patterson (1957) found out that I A A. accelerated early protonematal growth and increased the percentage of spore germination. But in the experiment on *Barbula indica* I A A. seems to have very little effect.

Induced productiou of rhizoids:

Several experiments were conducted in the hill stations of Kodaikanal and Ootacamund in two different seasons of the year, to induce the production of rhizoids from the foot of the sporophyte using the growth hormones.

The following species of mosses were available with sporophyte :

Ditrichum amoenum
Funaria hygrometrica
Bryum argenteum
Pohlia flexuosa
Anomobryum subniditum
Schlotheimia grevilleana
Thuidium tamariscellum
Atrichum aculeatum
Pogonatum microstomum
Pogonatum neesii

Fairly young sporophytes of the foregoing mosses were carefully removed from the tip of the gametophore and transferred into small vials containing the growth hormones in different concentrations. The hormones used were: (i) Indole-3- Acetic Acid; (2) Indole-Butyric Acid and (3) 2,4-D. Various concentrations of the hormones: .5 ppm., 1 ppm, 5 ppm., and 10 ppm. were prepared in distilled water. Besides, ane xtract of the gametophyte was also used. This was prepared by pounding the gametophytic part of the mosses in glass mortar after removing the sporophyte. The pounded material with

distilled water was used as such as an extract. A control in distilled water was kept for each experiment. Observations were taken every sixth hour for three days. The experiments were repeated every time with 10 sporophytes in each case. As rhizoids were formed only in I B A between 12 hours and 30 hours, the results have been tabulated accordingly as under:

TABLE–IX

Name of moss and duration	Gametophytic extract	No. of sporophytes producing rhizoids out of 10 — Indole-Butyric Acid .5 ppm.	1 ppm.	5 ppm.	10 ppm.
1	2	3	4	5	6
Ditrichum amoenum					
12 hrs.	—	—	—	—	—
18 hrs.	2	—	—	—	—
24 hrs.	—	—	—	3	—
30 hrs.	—	—	—	—	—
Funaria hygrometrica					
12 hrs.	—	—	—	—	—
18 hrs.	—	—	—	5	—
24 hrs.	3	—	—	—	—
30 hrs.	—	—	—	—	—

TABLE-IX (Contd.)

1	2	3	4	5	6
Bryum argenteum					
12 hrs.	1	—	—	—	—
18 hrs.	1	—		—	—
24 hrs.	—	—	2	—	—
30 hrs	—	—	—	—	
Pohlia flexuosa					
12 hrs.	2	—	—	3	—
18 hrs.	—	—	—	—	—
24 hrs.	—	—	—	—	—
30 hrs.	—	—	—	—	—
Anomobryum subniditum					
12 hrs.	—	—	—	—	—
18 hrs.	—	—	—	2	—
24 hrs.	4	—	—	—	—
30 hrs.	—	—	—	—	1
Schlotheimia grevilleana					
12 hrs.	—	—	—	—	—
18 hrs.	2	—	—	—	—
34 hrs.	—	—	1	—	—
30 hrs.	—	—	—	—	1

TABLE–IX (Contd.)

1	2	3	4	5	6
Thuidium tamariscellum					
12 hrs.	2	—	—	—	—
18 hrs.	—	—	—	3	—
24 hrs.	—	—	—	—	—
30 hrs.	—	—	—	—	—
Atrichum aculeatum					
12 hrs.	—	—	—	—	—
18 hrs.	2	—	—	—	—
24 hrs.	—	—	—	—	2
30 hrs.	—	—	—	—	—
Pogonatum microstomum					
12 hrs.	—	—	—	—	—
18 hrs.	—	—	—	—	—
24 hrs.	2	—	—	—	1
30 hrs.	—	—	2	—	—
Pogonatum neesii					
12 hrs.	—	—	—	—	—
18 hrs.	—	—	—	—	—
24 hrs.	3	—	—	—	—
30 hrs.	—	—	—	—	3

It may be observed that rhizoids have been produced in the extract of the gametophyte in all cases. Moreover, 5 ppm. of I B A has better effect on the formation of rhizoids from the tip of foot than other concentrations of the same hormone. Rhizoids are generally produced in larger number from the perichaetial region of the of the sporophyte than from the tip of the foot. The observations are in conformity with the findings of La Rue (1942), so far as the production of rhizoids are concerned. But, he stimulated rhizoidal production with I A A in lanolin and I B A in lanolin on detached leaves and sporophytes of several species of mosses. It is to be noted that in the present experiment I B A in distilled water itself induces the formation of rhizoids. It is not necessary that solution of I B A should be made in lanolin.

Osmotic concentration of gametophyte and sporophyte:

It is well known that the sporophyte of moss de pends partly on the gametophyte for its sustenance. The osmotic concentration of the cells of the gameto-phyte and of the sporophyte was studied with a view to find the difference in osmotic pressures in them. Plas-molytic method of de Vries was adopted using different concentrations of sucrose solution. Well developed leaves of mosses and thin free hand sections of the axis were also employed as the gametophytic tissue. Peels of the wall of the capsule specially from the apophysis region and sections of the seta near the capsule represented the sporophytic part. As Stocking (1956), Bonner and Galston (1951) have pointed out the concentration of the solution at incipient plasmolysis in about 50% of the cells, was taken as isotonic. The leaf cells and the

cells of the axis did not show any difference of osmotic concentration. So also, the difference in osmotic concentration of the cells of the capsule wall and the cells of the seta was negligible in most cases. The atmospheric temperature at Kodaikanal where these experiments were conducted was 20 C. Data of A. Ursprung, and G. Blum (1916) as quoted by Meyer, Anderson and Swanson (1955) were taken for the estimation of atmospheric pressures to different molarity. Only seven mosses were available with young sporophytes in sufficient quantities. The experiments were repeated several times to ascertain the proper isotonic solution and the observations are tabulated as under:

TABLE–X

Palsmolysis by Sucrose solution						
	LEAF (Gametophyte)			CAPSULE (Sporophyte)		
Name of moss	Concentration of sucrose %	Molarity	Osmotic pressure (O.p) at 20° Atm.	Concentration of sucrose%	Molarity	Osmotic pressure (O.p) at 20° Atm,
1	2	3	4	5	6	7
Bardula indica	5	.15	4	20	.58	17·1
Funaria hygrometrica	5	.15	4	25	.73	22.7
Anomobryum subniditum	15	.45	12.7	30	.88	28.8

TABLE-X (Contd.)

1	2	3	4	5	6	7
Bryum argenteum	30	.88	28.8	55	1.6	73 9
Thuidium tamariscellum (branch leaf)	10	.29	7.8	20	.58	17.1
Pogonatum microstomum	45	1.31	52.2	55	1.6	73.9
Pogonatum neesii	40	1.71	43.7	50	1.46	62.8

It may be seen that in all cases the osmotic pressure of the sporophyte is always higher than that of the gametophyte.

The ionising substances such as Sodium chloride and Potassium nitrate were also used for the determination of osmotic concentration in the same plasmolytic method. The isotonic percentages of the solutions which brought about incipient plasmolysis in the gametophytic and sporophytic tissues are tabulated. (Table-XI).

TABLE-XI

Name of mosses	Potassium nitrate (isotonic percentage)			
	Gametophyte		Sporophyte	
	Transverse section of axis	Leaf	T. S. of seta	Capsule
1	2	3	4	5
Barbula indica	—	5	30	30
Funaria hygrometrica	—	5	—	30
Anomobryum Subniditum	—	10	20	25
Bryum argenteum	—	7.5	—	25
Thuidium tamariscellum	10	10	20	20
Schlotheimia grevilleana	—	30	40	40
Rhegmatodon orthostegius	—	30	—	40
Pogontaum neesii	30	30	40	40

It may be seen that the cells of the sporophyte have higher osmotic concentration in all cases than the cells of the gametophyte.

Apart from the foregoing, biochemical tests were done in a rock moss *Schlotheimia grevilieana*. Kjeldahl's method of Nitrogen estimation was followed. Five grams (dry weight) of this plant were taken up. It was found after repeated experiments that 0.6260% of Nitrogen is present in this moss.

Ecological observations

Warming (1909) recognised the mosses as muscoid growth-forms and as a separate entity. For a proper ecological study of these forms, exact measurements of ecological factors, as rightly pointed out by Richards (1932) are needed. Though much more detailed study of the factors of the habitat of these mosses have to be made for entering into the inner realms of ecology, an attempt has been made to present the various factors that come into play in the study of the moss plants in their peculiarly complex environment.

Along with the external morphological details, the places of occurrence of the moss plants have been given in the preceding chapter. They are growing in the mountainous regions within the belt of 9° to 12° latitude and 76° to 79° longitude. (For map see elsewhere in this book). With in this area the most important moss growing places are the Kodaikanal (Kodai) Hills usually referred to as Upper Palnis in the Madura District and The Nilgiri Hills (Ootacamund or Ooty) in the Nilgiri District of South India.

Altitude : The altitude of the hills ranges between 1000 metres to 2900 metres. These hills are favoured with rain by two monsoon winds, the south west in

the months of May and June, the north east during October and November. The latter monsoon actually brings the little rainfall for this area. The monthly average rainfall and the maximum and minimum temperature of these two regions for three years consecutively during which period plants were collected, have been tabulated. (Table-XII).

TABLE - XII

MONTHLY AVERAGE TEMPERATURE AND TOTAL MONTLY RAIN FALL AT Kodaikanal

Month	1956			1957			1958		
	Temperature		Rain fall	Temperature		Rain fall	Temperature		Rain fall
	Maxi-mum oF.	Mini-mum oF.	in mm	Maxi-mum oF.	Mini-mum oF.	in mm	Maxi-mum oF.	Mini-mum oF.	in mm
1	2	3	4	5	6	7	8	9	10
January	61	45	49	63	45	2	63	48	23
February	62	45	5	65	47	29	64	49	12
March	68	51	29	66	49	33	66	50	186
April	66	53	159	67	52	160	67	52	164
May	68	54	67	67	54	120	68	55	240
June	64	53	128	66	55	106	69	55	53
July	62	51	25	63	53	135	63	52	60

TABLE-XII (Contd.)

1	2	3	4	5	6	7	8	9	10
August	63	52	187	63	53	142	64	53	121
September	63	52	124	64	52	112	65	52	114
October	61	51	348	63	52	285	63	52	177
November	60	50	343	61	50	349	63	50	211
December	61	46	57	61	49	197	61	46	48
Yearly total Rain fall			152.1			167.0			140.9

TABLE-XII (Contd.)

Ootacamund

Month	1956			1957			1958		
	Tempe-rature		Rain fall	Temperature		Rain fall	Tempera-ture		Rain fall
	Maxi-mum oF.	Mini/mum oF.	in mm	Maxi-mum oF.	Mini mum oF.	in mm	Maxi-mum oF.	Maxi-mum oF.	in mm
1	2	3	4	5	6	7	8	9	10
January	73	37	7	77	33	0	73	40	2
February	72	38	0	76	39	9	74	41	24
March	79	45	0	72	41	38	72	45	136
April	79	48	136	75	47	46	75	47	45
May	77	49	83	71	50	670	78	51	187
June	72	50	169	69	51	153	72	52	75
July	67	49	80	66	50	100	66	51	213

TABLE-XII (Contd.)

1	2	3	4	5	6	7	8	9	10
August	70	48	63	71	51	77	70	50	198
September	71	49	59	74	45	25	71	46	80
October	71	48	389	71	50	257	7,	48	102
November	70	46	138	70	49	233	71	44	228
December	72	38	14	71	44	91	70	40	7
Yearly total Rain fall			114.7			169.9			129.7

Temberature

It may be seen that the range of temperature is 33 F, to 79° F. and yearly rainfall is between 100 cc. to 170 cc. There is no snow fall but ·during the winter months of December and January, the hills are covered by mist specially towards the evenings. It is interesting to note that many species of mosses such as *Bryum argenteum*, and *Funaria hygrometrica* of the temperate climate grow fairly well in these regions. The tropical moss families, are well represented in this belt such as *Pterobryaceae* with 10 species, *Meteoricaceae* with 20 species, *Hookeriaceae* with 6 species and *Sematophyllaceae* with 27 species according to Foreau's list (1961). Only a few species in each of these families could be collected and still fewer have been dealt with in this study.

Apart from their growing in the hills, *Barbula indica* (Fig. 488) and *Leucobryum* neilgiriense (Fig. 485) are growing on the plains very luxuriantly.

The Dry and Wet Bulb Thermometer was used to record the range of temperature in the field conditions. Daubenmire (19 7) advocates the use of this kind of hermometers, for obtaining the temperature as it is easy to work out the atmospheric pressure and the relative humidity of the locality with these readings.

The readings were noted on the high mountainous localities where the mosses are growing well, every half-and hour of the day between 10 A M. to 3 P. M. in two different seasons just to gain an idea of the climatic conditons of the moss area. The readings are tabulated (Table-XIII).

TABLE-XIII

Name of the mosses	Locality	Altitude in metres	Weather condition					
			October			May		
			Thermometer reading		Nature of weather	Termometer reading		Nature of weather
			Dry	Wet		Dry	Wet	
1	2	3	4	5	6	7	8	9
Bryum argenteum	Nilgiris				Rainy, windy			Bright sun-shine
Petrobryopsis frondosa	Thodda-bedda peak	2900	60–64	52-58	and clouded	70-76	70-74	
Rhodobryum giganteum								
Pleuropus nilgiriense	Kodi							
Barbella tenax	Silver caskade	2000	54-58	52–54	Clouded	70–72	68–70	Bright

TABLE XIII (Contd.)

1	2	3	4	5	6	7	8	9
Pogonatum								
neesii	Nilgiris							
Mnium								
longirostrum	Fern hill	2500	56-62	52-56	Misty	70–78	68-72	Clouded
Homaliodendron	Kodai							Moist
flabellatum								
Entodon								windy
plicatus	Priest's							
Papillaria	walk							
crocea		2300	60-62	56-58	Drizling	70-74	72-74	
Barbula indica	Annamalai-nagar	10	80-86	70–78	Bright day	84-90	80-88	Dry

There are variations, as may be seen, at different altitudes at different places during the same hours of the day. The change in temperature was also due to the wind which blows rather violently often carrying clouds with them specially at Doddabetta, the highest peak in South India.

When the temperature is at its maximum (104°F.) the local moss *Barbula indica* is almost dead or dormant waiting for the onset of rains or sprouting out when water is supplied artificially.

Humidity

To measure the humidity, the psychometric tables (Weather Bureau U.S. Commerce Department 1941) were employed as indicated by Daubenmire (1947) There is difficulty in the calculation of humidity as it varies differently in different hours of the day and night and also at different seasons.

Wind profoundly affects the vegetation of mosses. The forest trees like *Lasianthus venulosus* Wt. are clothed with many moss plants (Frontispiece). Richards (1932) has observed that the "effects are particularly obvious on epiphytes." There are also a few species growing on the top of high mountains exposed to the wind.

Pure formations of the local moss *Barbula indica* are found on the terrace of the botanical laboratory during winter season of November and December. The relative humidity during the day varies from 65 to 90. It is at this period that this moss produces capsules. This observation is in conformity with the findings

of Schimper (1903) "that high atmospheric humidity promotes growth and depresses transpiration" Though this plant is abundant both in the plains and found in the hills, it has never been observed to produce capsules in the hills for several years.

Light

Richards (1932) has observed that "the study of light factor presents special difficulties. The usual methods for measuring its intensity are admittedly unsatisfactory and its effects are very hard to disentangle from those of humidty and temperature" Many moss communities such as *Bryum argenteum*, *Brachymenium exile*, *Pogonatum microstomum*, *Schlotheimia grevilleana*, *Barbula indica* and others are exposed to rather high light intensities. *Ditrichum amoenum* and *Homaliodendron flabellatum* were found to grow away from sunshine inside the caves. The following mosses such as *Rhizogonium spiniforme* and *Rhodobryum giganteum* grow in shady habitats.

Water

Apart from the intermittent or periodical showers of rain, water keeps oozing from the substratum so well that the mosses growing on the slopes receive a continual supply.

The atomspheric moisture is another source of water for the mosses in the hills. The epiphytic mosses such as *Floribundaria*, *Meteoriopsis* and *Papillaria* which are exposed to dessication "are able to seize the momentary opportunity and in their dry condition can instantly absorb moisture over their whole surface, e g. algae,

mosses'' Warming (1909). While speaking about the muscoid and lichenoid growth forms, he says, "their powers of enduring extreme loss of water and of rapidly replacing this by means of absorption over the whole free surface are ecologically very important "

Edaphic factor

The soil is of various kinds in this area, such as rocky, black loamy and humus. The following mosses are growing on tree trunks forming a carpet; *Sematophyllum subhumile, Pterobryopsis orientalis, Pleuropus nilghiriense* and *Aerobryopsis longissima.*

The following mosses are hanging from the branches of trees in the form of festoons: *Papillaria crocea* (Frontis piece) *Floribundaria floribunda, Barbella pendulla, Meteoriopsis reclinata, Rhizogonium spiniforme* and *Leucobryum scalare* grow in small patches on dead tree trunks.

The behaviour of growth of *Barbula indica* is interesting. It occurs on the open terraces of old buildings, on brick walls exposed to sun and rain It is surprising to comprehend the perennation of such a delicate moss in the tropical isolation of Annamalainagar. When an entire patch of germinating moss plants was examined, it was found that there is always a tangle of *Oscillatoria* forming a mat beneath. Such patches do not form at all on the same terrace where there is cement plastering, as no *Cyanophyceae* develops there. The statement of Warming (1909) that algae may form the lower stratum for the formation of mosses is in support of this observation. Chapman (1950) has

pointed out that filamentous Cyanophyceae are capable of retaining moisture. Therefore, the occurrence of *Barbula indica* in such a hot climate may be correlated to the presence of filamentous *Oscillatoria* offering protection to the germinating spores and gemmae of the moss plant. Further, it is but appropriate to quote the temperature tolerance of the same genus of moss and blue-green alga from the hand book of Biological data edited by Spector (1956).

Tolerance to Extremes of Heat: Moss

Moss	Temperature °C.
Barbula gracillis	110–115

Temperature tolerance Extremes: Algae

Species	Maximum for habitat °C.	Maximum tolerated °C.
Oscillatoria amphibia	50	-
Oscillatoria filiformis	85.2	85.2
Oscillatoria formosa	50	-
Oscillatoria geminata	45	-
Oscillatoria okeni	44	-

However, Desikachary (1959) while referring to thermal algae, has quoted Elenkin (1914) who stated that the Cyanophyceae tolerates a maximum temperature of

85°C. It may be seen, therefore, that *Barbula indica* in the tangle of *Ocillatoria* filaments has been able to be tided over the maximum temperature of 104°F. (40°C) in the tropical isolation of Annamalainagar.

Quadrat studies on this moss were also made. Two sets of 10 c.m. quadarats were isolated each set with a control side by side. One of the quadrats of each set was denuded and observations were taken for about a month. On the third day the *Cyanophyceae* made its appearance in the denuded quadrats and on the 10th day the moss protonema was found to develop and after 20 days they were full of young moss plants. These plants were so small that they were in close aggregation. Actual counting of the 10 cm. quadrat reveals that there are 25,000 to 26,000 moss plants in pure formation.

The following mosses grow on rocky substratum: *Homaliodendron flabellatum*, *Schlotheimia grevilleana*, *Thysanomitrium depallieri*. Of these, *Homaliodendron flabellatum* known as the fan moss grows in a horizontal manner directly from moist rocks in thick forests. *Schlotheimia grevilleana* (Fig. 543) forms a thick and beautiful carpet covering rocks exposed to the sun. The plant is provided with reddish branched rhizoids in large numbers. *Thysanomitrium depallieri* is dark green growing in the sun on soil covered rocky slopes where water keeps oozing.

The two species of *Pogonatum* (Figs. 548 & 549) grow on soil in pure formation specially on the cuttings of the road side at higher altitudes extending several

metres. *Mnium coriaceum*, *Rhodobryum giganteum* (Fig. 540) and *Hypopterygium tenellum* grow on loose soil in damp and shaded forests. *Bryum argenteum* and *Anomobryum subniditum* grow on the crevices of rocks and culverts as Chasmophytes. *Brachymenium exile* and *Fissidens schimidii* (Fig. 538) grow in black loamy soil in shaded situations. *Funaria hygrometrica* likes to grow in the damp regions where there was a forest fire. This observation has also been made by Watson (1954) and Dunham (1951). Therefore, it may be pointed out that this sort of soil is a kind of plant indicator.

When all these physiographic and edaphic factors are present and while many of the moss plants are producing the capsules, there still remains a mystery that some mosses do not seem to produce capsules at all in spite of their very luxuriant growth. It is yet to be known whether the absence of capsule in such mosses suggests that the gametophytic phase has come to be established once and for all as permanent feature without any prospect of giving rise to the sporophytic phase, or, whether, this is just a temporary means of propagating the gametophytic phase for a prolonged period.

The association of some of the mosses with other plants was studied in the manner inidcated by Gams (1932) in order to understand the relative frequency of the species. The observations are tabulated as follws:

TABLE-XIV

	Bryum argenteum	*Mnium coniaceum*	*Papillaria crocea*	*Thuidium tamariscellum*	*Meteoriopsis reclinata*	*Pleuropus nilghiriense*	*Entodon plicatus*
Brachymenium exile	+ + + +	+					
Rhodobryum giganteum	+	+ + + +					
Pterobryopsis frondosa			+ + + +		+		
Trachypus bicolor			+	+ + + +			
Barbella tenax				+ +	+ + + +		+ +
Floribundaria floribunda					+	+ + + +	
Sematophyllum subhumile							+ + + +

TABLE-XV

Mosses with other bryophyta or lichen or on angiosperms

	Cladonia	*Pellia*	*Usnea*	*Coleus*	*Lasianthus venulosus*	*Syzygium arnottianum*	*Rhododendron nilagiricum*	*Plectranthes weghtii*
Bryum argenteum	+ +							
Hypopterygium tenellum		+ +						
Pogonatum microstomum	+			+ +				
Papillaria crocea			+		+ +			
Sematophyllum subhumile						+ +		
Hypnodon perpusillus								+ +
(*Rhegmatodon*)								
Pterobryopsis frondosa							+ +	

Biotic factor :

This may include, besides the foregoing, the zoological organisms which take shelter under the moss formations. Some millipedes, *Xenobolus acuticonus* Att. were found under the thick carpet of *Schlotheimia grevilleana.* The profusely branched rhizoids afford suitable accommodation for these creatures. The crevices of the bark of forest trees like *Syzygium arnottianum*, *Lasianthus venulosus*, *Rhododendron nilagiricum* and *Plectranthes wightii* in which some of the epiphytic mosses like *Barbella* and *Rhegmatodon* spread their rhizoids, form natural abode of many insects like *Thyroglutus* sp. The leeches, *Haemadipsa* spp., are found in abundance generally with *Rhodobryum giganteum* especially in the Tiger Shola of Kodaikanal. It fact the leech is indicative of the presence of this moss Similarly in the tuft of *Thuidium*, another millipede, *Sphaerotherium* sp. is always found.

Further, moss carpets of *Pogonatum microstomum* have been found to provide seed beds for flowering plants like *Coleus ovatus* (Fig. 548). It may probably be due to the water retaining capacity of the mosses as Richards (1932) has pointed out.

The South Indian mosses under this study have been classified ecologically in the scheme of classification suggested by Gams (1932).

1. ADNATA

   Mosses on firm ground are.-

   Bryum
   Fissidens
   Pogonatum

1. ADNATA (Contd.)

Dicranum
Ditrichum

2. RADICANTIA

Mosses on loose ground are:-

Rhodobryum
Mnium
Philonotis
Funaria

3. AMPHINEREDIA

Mosses periodically submerged are:-

Hookeria
Thysanomitrium

4. EPIPETRIA

Mosses confined to rocks are:-

Schlotheimia
Barbula
Pleuropus
Homaliodendron

5. EPIPHYTIA

Mosses on the bark of trees are.-

Rhizogonium
Hypnodon
Pterobryopsis
Meteoriopsis
Papillaria
Leucobryum
Barbella

6. HELOPHYTIA

Mosses that are peat-forming on very wet soil are:
Thysanomitrium
Herpetineurum

7. AMPHIPHYTIA

Mosses with periodically inundated soil are
Rhodobryum
Mnium
Hypopterygium

8. CHASMOPHYTIA

Mosses on mineral soil are:-
Bryum
Barbula

9. BRYOCHAMAEPHYTIA

Mosses on humus soil are:-
Thuidium
Atrichum

10. SYMBIOPHYTIA

Mosses with other plants are:-
Rhegmatodon
Sematophyllum
Erythrodontium

The other two groups of Gams (1932) such as *Nereidia* and *Epiphyllia* could not be observed under this collection.

Discussion

1) Morphological and Physiological peculiarities of mosses in relation to their ecology

The morphological delajls of the 64 species of South Indian mosses are generally ın accordance with the findings of the earlier bryologists (Cardot & Varde) (1922), Brotherus (1899), Dixon&Varde (1927). However, the height of the plant, the length and breadth of the leaves, the length of seta and the dimensions of the capsule are in certain cases, slightly variable. This may be due to regional and / or seasonal changes.

a) Vegetative adıptation:

The presence of dorsal lamellae in the leaves of *Fissidens* (Fig. 5), the papillose cells in the leaves of *Thuidinm tamariscellum* (Fig. 284) and the occurence of rows (lamellae) of cells as outgrowth on the upper leaf surface of *Pogonatum* (Figs. 349 & 354) have been considered to be of significance for the retention of water. Further, the leaf of *Leucobryum* which is mostly *multicellular* contains chloroplasts only in a few cells and the rest are without chloroplasts. This sort of spongy construction appears to be a device for the retention of water as pointed out by Goebel (1905).

The laminar cells of *Trachypodopsis serrulata* (Figs. 208 & 209), *Barbella tenax* (Fig. 238), *Floribundaria floribunda* (Fig. 242), *Erythrodontium julaceum* (Fig. 304) are very much thick-walled. The thickening of the cell-wall in these species, may be due to their xerophyllous habit. It is probable that the thickening of cell–walls serves for holding water obtained from mist, dew and rain by the process of imbibition. Warming (1909) while referring to epiphytes has stated that "many are able to seize the momentary opportunity and in their dry condition can instantly absorb moisture over their whole surface e.g. Algae, mosses, lichens."

Bryum argenteum derives its name from the silvery appearance of its shoots. The upper half of the leaves is responsible for this appearance. Goebel (1905) has stated that "these dead upper parts invest as with a mantle, the bud of the stem and must check the outgo of water."

The apex of leaf in the following species of mosses is hair–like: *Brachymenium exile* (Fig. 130), *Brachymenium leptostomoides* (Fig. 136), *Bryum argenteum* (Fig. 145), *Trachypus humilis* (Fig. 200), *Aerobryopsis longissima* (Fig. 225), *Barbella determessi* (Fig. 233), *Barbella pendula* (Fig. 237), *Warburgiella leptorhynchoides* (Fig. 319), *Hypnum cupressiforme* (Fig .323), and *Taxiphyllum taxirameum* (Fig. 327). The dense aggregation of the hair point in the younger leaves may be another safeguard against drought.

The rhizoidal felt of the mosses may play an important role in the conservation of moisture. This is more so

specially in the lythophytic mosses such as *Homaliodendron flabellatum* and *Schlotheimia grevilleana.* This observation was made by Warming (1909).

It may be seen from a perusal of the anatomical description of the mosses (pp. 86 - 105) that in most of the species, the axis is provided with a peripheral rind of thick-walled cells. The tubular structure of the axis so constructed is perhaps to afford mechanical strength to the otherwise flimsy and delicate mosses. It is likely that the rind is also but a device to retain the water by the process of imbibition apart from its being a protective layer.

b) **The sporophyte:**

Out of 64 species studied, sporophytes were available in 34 mosses only and they have been examined in some detail. The nature of looping of the seta may have a bearing on the "need for the regulation of spore dispersal." Eight different forms of foot of the sporophyte have been observed in the different species of mosses.

Stomata were found only in 8 species. It may be seen from Tables IV and V that the stomata are characteristic of the species and they resemble those of the angiosperms. L B (Length/Breadth) ratio of the stomata is constant and the stomatal index is specific of the mosses. The number of subsidiary cells of the stomata in mosses is variable being 8 to 13. The epidermal cells of the sporophyte of *Trematodon ceylonensis* are much elongated, resembling those of the sporophyte of *Anthoceros pearsoni*. These observations

are in conformity with Bower (1934) who has compared the photosynthetic system of the Psilophytales with that of the Anthocerotales. He has also quoted Goebel as saying that "there is no doubt that many moss capsules show clearly traces of a reduction of the photosynthetic system of the stomata closely related to it - all this indicates that moss sporangia originally possessed a structure similar to that of *Anthoceros*." Further, Goebel (1905) while speaking about the stomata of the mosses has said that "it is remarkable that in the Bryophyta the formation of stomata repeatedly appears as for example in *Anthoceros* and in the different series of the Musci and they in every way correspond with the stomata of the spermatophyta."

Lorch (1926) discovered protoplasmic links between the cells of the foot and those of seta in some 300 mosses. The foot of the sporophyte is always buried more or less deeply in the tissue of the gametophore. Goebel (1905) has observed that in *Eriopus remotifolius* rhizoids are developed at the point where "the sporogonium sits within the ruffle-like vaginula." He has further recorded that "the only example I know of a sporangium rooting by rhizoids." La Rue (1942) successfully stimulated rhizoidal formation all over the detached sporophytes by wounding and by using wound and growth hormones dissolved in lanolin. It the present investigation the sporophyte of 10 species of mosses were induced to develop rhizoids by hormones and thereafter they could lead independent existence. The idea behind these experiments was to find out whether the moss sporophyte could be induced to live indepen-

dently for some length of time. It is interesting to note that under the influence of hormones and gametophytic extract they do produce rhizoids from the base of the foot and they are able to exist independently without the gametophyte though for a short duration of 36 hours. The only other report of a bryophyte known to lead an independent existence is by Campbell (1925) in the case of *Anthoceros fusiformis*. but so far no sporophyte of a moss is known to behave similarly.

The sporophyte of moss with rhizoids therefore appears to have attained a "Psilophytalean status" in its external morphology. It superficially resembles *Horneophyton* with its columellate sporangium. The lacuna in this correlation is the absence of vascular elements in the sporophyte of moss. It is not claimed however, that the gap between the Bryales and the Psilophytales has been bridged by the independent existence of the moss sporophyte. When it can secure this independent existence of 36 hours by Indole-Butyric Acid it may be possible by better culture methods that the moss sporophyte may be induced to become independent for a longer duration.

It may also be pointed out that this observation is an added support to the view of Scott (1923) who referring to Psilophytales, has said that "a certain affinity with the Bryophyta has also been recognised and it has even been held that the Rhyniaceae should be assigned to this sub-kingdom. The Sphagnum-like structure of the columellate sporangium or sporogonium of *Hornea* and *Sporogonites* may be regarded as

ssupporting the Bryophytic attribution which may them readily be extended to *Rhynia*."

c) **Osmotic concentration:**

The osmotic concentration of the cell-sap of the gametophyte and that of the sporophyte of 7* mosses' has been determined for the first time by de Vries, Plasmolytic method (*Table* X). The experiments were made in Kodaikanal hills during the month of October 1960.

TABLE XVI

Osmotic perssure of sporophyte and gametophyte

Name of moss	Sporophyte O.P. in atm.	Gametophyte O.P. in atm.	Difference in atm.
1	2	3	4
Barbula indica	17.1	4.0	13.1
Funaria hygrometrica	22.7	4.0	18.7
Anomobryum subniditum	28.8	12.7	16.1
Bryum argenteum	73.9	28.8	45.1
Thuidium tamariscellum	17.1	7.8	9.3
Pogonatum microstomum	73.9	52.2	21.7
Pogonatum neesii	62.8	43.7	19.1

* Only 7 species were available with sporophytes at that time.

It may be seen from Table XVI. that the osmotic concentration of the sporophyte of each species is always higher than the osmotic concentration of the cerresponding gametophyte. The range of difference of the osmotic pressure between the sporophyte and the gametophyte varies from 9.3 atmospheres (*Thuidium tamariscellum*) to 45.1 atmospheres (*Bryum argenteum*). The osmotic concentration of the sporophyte is very high. It may be due to the fact that the food material has to be transported from the gametophyte to the sporophyte.

d) Ecological factors and their significance

The South Indian mosses grow at an altitude of 1000 metres to 2900 metres in the tropical belt of 9° to 12 north latitude and 76° to 79° east longitude. The atmospheric temperature varies from 33°F to 79°F and annual rainfall is between 100 c.c. to 170 c.c. The moss flora is generally rich on the slopes of steep mountains and in the moist regions of the downs The mosses there fore enjoy a peculiar limited climate known as the "local climate" as Tansley (1946) would put it. He has stated that "Altitude, slope and exposure determine what is called "local climate," affecting the temperature, rainfall, air moisture and insolation to which a given piece of vegetation is exposed and therefore to a large extent the particular species of plant that form it."

The occurrence of tropical moss families in South India in large number of species may be due to the various climatic conditions. As has been pointed out already (p. 118) it is significant that many species of

temperate climate are growing fairly well in this area at high altitudes.

Low temperature at high altitude in the tropics seems to account for the luxuriant growth of the rich vegetation of mosses in this region as the moss plants are endowed with " powers of assimilating apparently at very low temperatures more readily than can spermatophyta " (Warming, 1909).

Some species of South Indian mosses have been observed to grow in two different "discontinuous areas" (Wolff, 1924) of almost similar altitudes. The following mosses grow nearly at the same altitude of both Kodaikanal hills and Ootacamund hills though they are about 300 miles apart from one another :

Ditrichum amoenum	2300 metres
Meteoriopsis reclinata	2200-2300 metres
Papillaria crocea	2500-2600 metres
Distichophyllum succulentum	2000 metres
Atrichum aculeatum	2500-2600 metres
Pogonatum neesii	2600-2800 metres

2) **Taxonomical considerations on the basis of anatomical observations**

(a) **Structure of the moss axis :**

The transverse sections of the axis of the 53 species of South Indian mosses studied here, exhibit various peculiarities. As has been pointed out already (p. 96) the following anatomical features may be noticed :

(i) The axis of most of the mosses, is provided with a peripheral rind.

(ii) The axis of a few of them are not provided with this rind.

iii) The axis may possess a well-defined central strand in the centre which may or may not be differentiated.

iv) The axis may not possess a central strand but the tissue inside the rind may be differentiated into a pith or cavity or there may be a small cell situated in the centre surrounded by a ring of radiating cells. Sometimes the tissue inside the rind may not be differentiated and it may be made up of uniformly thin or thick-walled cells.

Having these facts in view, a classification of the mosses (53 in number) on the basis of the anatomical structure of the gametophyte, has been erected. This classification is merely an attempt to group the various mosses and it does not aim at phylogeny or evolution.

b) Systems of classification:

Natural system of classification was proposed by Hedwig (1801) and Jaeger and Sauerbeck (1870-78) followed it. Later Brotherus (1901) erected a classification which according to Dixon (1932) "does not greatly differ from that of Jaeger in general arrangement" and it has been based on the classification of Fleischer (1906-1908) in most respects. In 1932, Dixon proposed his classification. Phylogenetic arrangement of the true mosses was proposed by Schaffner (1938). He has stated that "Brotherus

(1924-1925) is much better than Dixon in his arrangement of the general progressive sequence of the groups from the lower to the higher evolutionary levels." He has added that, "Archidales are plainly the lowest group and the Polytrichales the highest. The Archidales do not represent reduced or degenerate species but are truly primitive in their characteristics."

The different systems of classiffcation of mosses according to Brotherus (1924), Dixon (1932), Schaffner (1939), Conard (1956) and Watson (1954) represented diagramatically in Plate LXII. All these systems are based mainly on the characters of the peristome. As the classification of Grout (1524) resembles that of Conard (1956) in the main it has not been repersented here.

It may be seen that Schaffner (1939) and Brotherus (1924) separated off the Polytrichales from the rest of the mosses while others place the Polytrichales in the middle of the scheme. Thus the systematic position of the Polytrichales is highly disputed. Cavers (1911) in his inter - relationships of the higher Bryophyta, has separated the Polytrichales away from the Bryales.

The anatomical observations of this group in the present investigation are only meagre as three species alone were examined. However, these three species of the Polytrichaceae stand out as a peculiarly different type of mosses from the rest. The axis has a well defined central strand unlike the other mosses. The leaves contain many rows of lamellae-a feature not found in other mosses.

Summary

Studies in the morphology, anatomy, physiology and ecology of 64 different species of more common South Indian mosses have been made in some detail.

Morphology:

Many of South Indian mosses have been reported to occur in other countries also and they were identified and taxonomically described long ago by Cardot (1911), Dixon (1914), Cardot & Varde (1922), Varde (1922-1925), Hedwig (1864), Dixon & Varde (1927), Fleischer (1905-1908), Brotherus (1899), and others. Some of the species were collected even from South India and described by these authors. A few others have been redescribed and specific names corrected. Excepting these sporadic morphological descriptions, there has hardly been any comprehensive work on the South Indian mosses. The present investigations on South Indian mosses, therefore, have been made for the first time in a detailed manner.

On closer examination of the mosses in detail, it has been found that the morphological observations such as the shape, margin, apex and phyllotaxy of the leaves are in conformity with the original description. The lamellar structure of the leaves, the papillose nature of the laminar cells, the absence of chloroplasts in some cells of certain leaves, the excurrent costa and

acuminate apex of leaves and the rhízoidal felt may be adaptations for retention of water These observations conform to the observations by Goebel (1905) on mosses of other regions.

Certain observations on the sporophyte such as the following are reported for the first time:

(a) Out of 34 available sporophytes examined, 8 different forms of foot have been recognised so far.

(b) Linear measurements of the capsule and foot reveal that there is corresponding increase in length of the foot *pari-passu* with the increase in length of the capsule. The peristome and the spores have been studied in detail.

(c) The opercula have been classified under four groups conforming to the classification of Dunham(1951).

(d) The L/B (Length/Breadth) ratio of the stomata found on the apophysis of 8 species of mosses appears to be a constant factor. The stomatal index of each one of the mosses also appears to be specific.

Vegetative reproduction has been recorded: by means of bud-like bulbils in 3 species, by means of multicellular gemmae in 3 species, regeneration by the formation of rhizoids from detached or attached leaf or stem in 4 species and by the production of "rhizoprotonemata" in *Barbula indica*.

Anatomy:

Transverse sections of axes of 53 South Indian species have been described for the first time. This anato-

mical observation has led to a classification of these mosses on the basis of their structure. The proposed system of classification though based purely upon anatomical details of the gametophyte, is in conformity with the prevailing systems of classification of Brotherus (1924) and Schaffner (1938) in some respects.

Physiology:

Physiological observations have exhibited that the sporophyte of the moss can be induced to produce rhizoids by treatment with hormones and thereafter it may be induced to lead an independent existence for a short time. The moss sporophyte, thus with its rhizoids arising from the base of the foot, appears to have attained a "psilophytalean" status in this regard. It may be compared in its external morphology to *Hornεo-phyton* with its columellate sporangium, a comparison at best superficial as the moss sporophyte is not provided with any vascular element.

The osmotic concetration of the sporophyte of 10 species and that of their corresponding gametophytes have been determined for the first time. It has been found that osmotic pressure of the sporophytes is always higher than that of the gametophytes. This may be explained on the basis of transport of food from gametophyte to the sporophyte.

Ecology:

The natural home of the South Indian mosses is situated within the square of 9° - 12° North Latitude and 76° -79° East Longitude (Map elsewhere). The range of temperature is between 33°F and 79°F. and the annul rainfall between 100 cc. and 170 c.c.

The soil of occurrence of *Funaria hygrometrica* is a plant indicator. It has been found that it grows in regions where there was a forest-fire. This observation is in support of the findings of Dunham (1951) and Watson (1954).

The perennation of *Barbula indica* in the tropical isolation of Annamalainagar has been found to be due to the presence of *Oscillatoria* sp. forming the substratum for the mosses. Both the genera are capable of tolerating high temperature of 104 F. (40°C). This is in conformity with the report of Spector (1956).

The presence of *Rhodobryum giganteum* is indicative of the presence of a leech *Haemadipsa* sp. in the habitat and conversely the leech is indicative of the presence of this moss.

The association of mosses with other mosses and mosses with other plants have been recorded (pp. 127–128) in respect of South Indian mosses. Further. these are classified into 10 groups in the scheme of classification of Gams (pp. 129–131).

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PLATES

PLATE I

Fissidens schimidii C. M.

Figure 1. Showing plant with leaves and sporophyte. X 1

Figure 2. Showing plant with leaves and sporophyte. X 10

Figure 3. Leaf showing the characteristic appendage. X 75

Figure 4. Cells of leaf. X 285

Figure 5. Transverse section of leaf showing the dorsal lamella the appendage as outgrowth. X 285

Figure 6. Peristome. X 258

Ditrichum amoenum (Thw. and Mitt.) Par.

Figure 7. Showing plant with leaf and aporophyte. X 1

Figure 8. Showing plant with leaves of gametophyte. X 10

Figure 9. Leaf showing shape. X 20

Figure 10. Cells of leaf. X 285

Figure 11 Capsule showing shape. X 20

Figure 12. Peristome. X 285

Trematodon ceylonensis C. M.

Figure 13. Showing plant with leaf and sporophyte. X 1

Figure 14. Showing plant with leaf and sporophyte. X 10

Figure 15. Leaf showing shape and apex. X 75

Figure 16. Cells of leaf. X 285

Figure 17. Capsule showing shape. X 20

Figure 18. Stomata on the wall of capsule near apophysis. X 490

Figure 19. Peristome. X 285

PLATE I

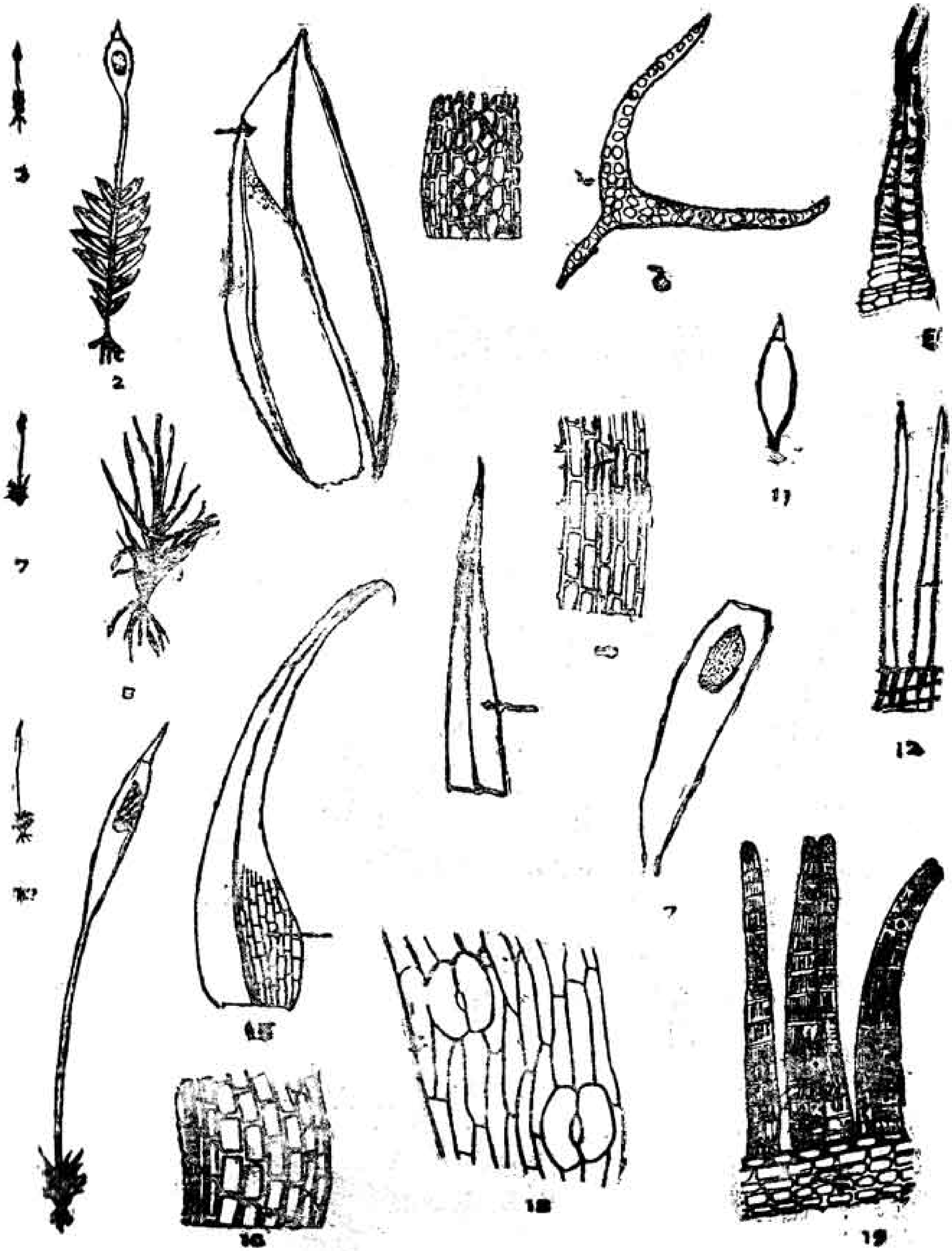


PLATE II

Campylopus nodiflorus (C. M.) Jaeg.

Figure 20. Showing plant with leaves and sporophyte X 2
Figure 21. Leaf showing shape. X 20
Figure 22. Leaf showing apex. X 285
Figure 23. Cells of leaf in the middle of lamina. X 285
Figure 24. Alar cells. X 285
Figure 25. Capsule showing shape. X 20
Figure 26. Annulus. X 285
Figure 27. Peristome. X 285

Thysanomitrium depallieri Card.

Figure 28. Showing plant with leaves. X 2
Figure 29. Leaf showing shape and margin. X 20

Thysanomitrium lioneurum (Ther. and Vard.) Broth.

Figure 30. Leaf showing apex. X 285
Figure 31. Alar cells of leaf. X 490
Figure 32. Cells of leaf. X75
Figure 33. Showing plant with leaves. X 2
Figure 34. Leaf showing shape X 15

Thysanomitrium depallieri Card.

Figure 35. Showing apex of leaf. X 285

Thysanomitrium lioneurum (Ther. and Vard.) Broth.

Figure 36. Cells of leaf. X 75
Figure 37. Cells of leaf. X 285

Brothera leana (Sull.) C. M.

Figure 38. Showing plant with leaf. X 2
Figure 39. Leaf showing shape. X 30
Figure 40. Leaf showing apex. X 285
Figure 41. Cells of leaf. X 285

PLATE II

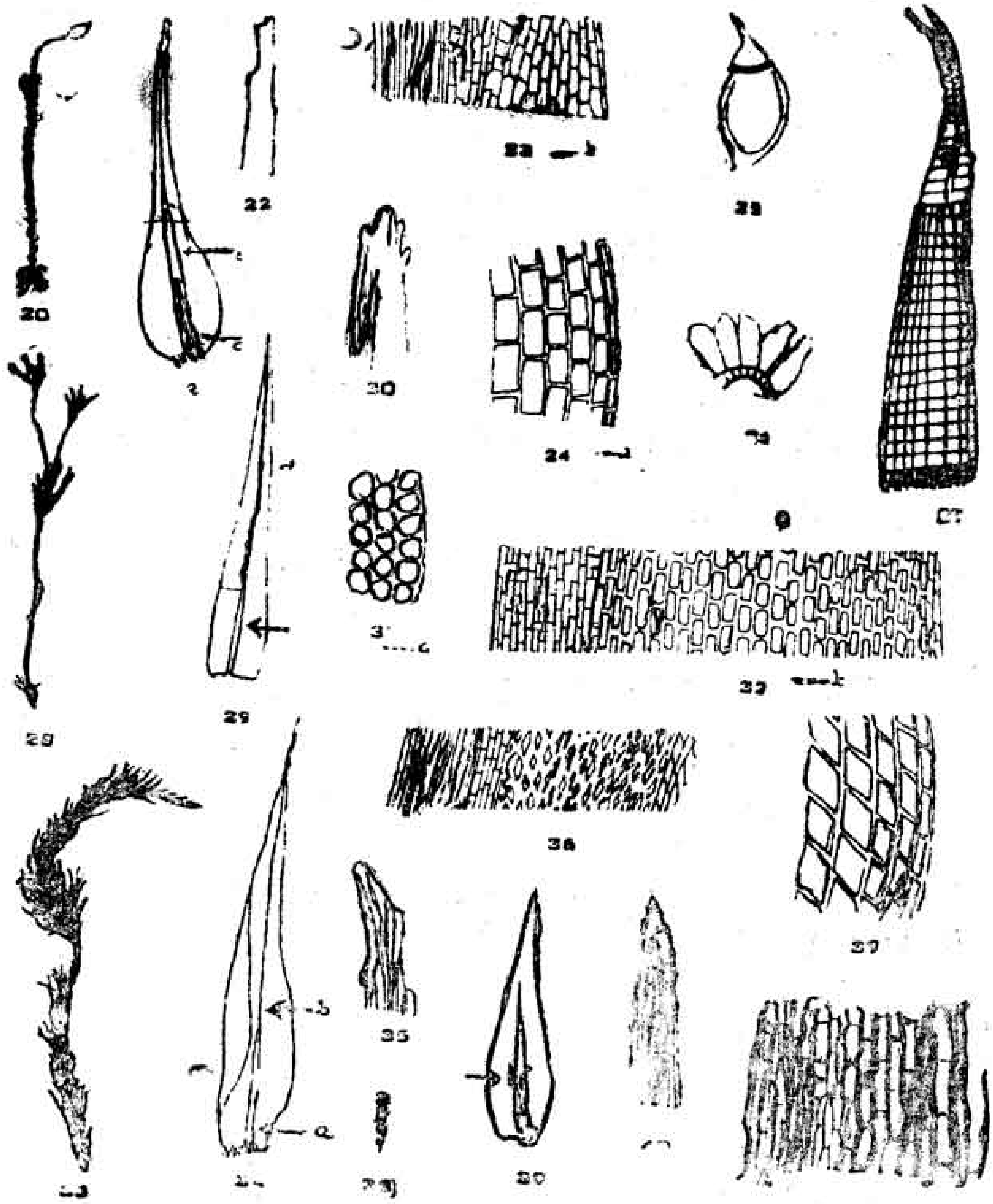


PLATE III

Dcranodontium fragile (Hook.) Broth.

Figure 42. Showing plant with leaf and sporophyte. X 2
Figure 43. Leaf showing shape. X 75
Figure 44. Leaf showing apex. X 285
Figure 45. Alar cells of leaf. X 285
Figure 46. Showing form of capsule. X 20
Figure 47. Peristome. X 285

Leucobryum neilgherrense C. M.

Figure 48. Showing plant with leaves and sporophyte. X 2
Figure 49. Leaf showing shape. X 40
Figure 50. Leaf showing apex. X 285
Figure 51. Transverse section of leaf. X 75
Figure 52. Cells of leaf. X 285
Figure 53. Capsule showing shape. X 20
Figure 54. Peristome. X 285.

Leucobryum scalare C. M

Figure 55. Showing plant with leaves. X 2
Figure 56. Leaf showing shape. X 40
Figure 57. Leaf showing apex. X 285
Figure 58. Transverse section of leaf. X 75
Figure 59. Cells of leaf. X 285

PLATE III

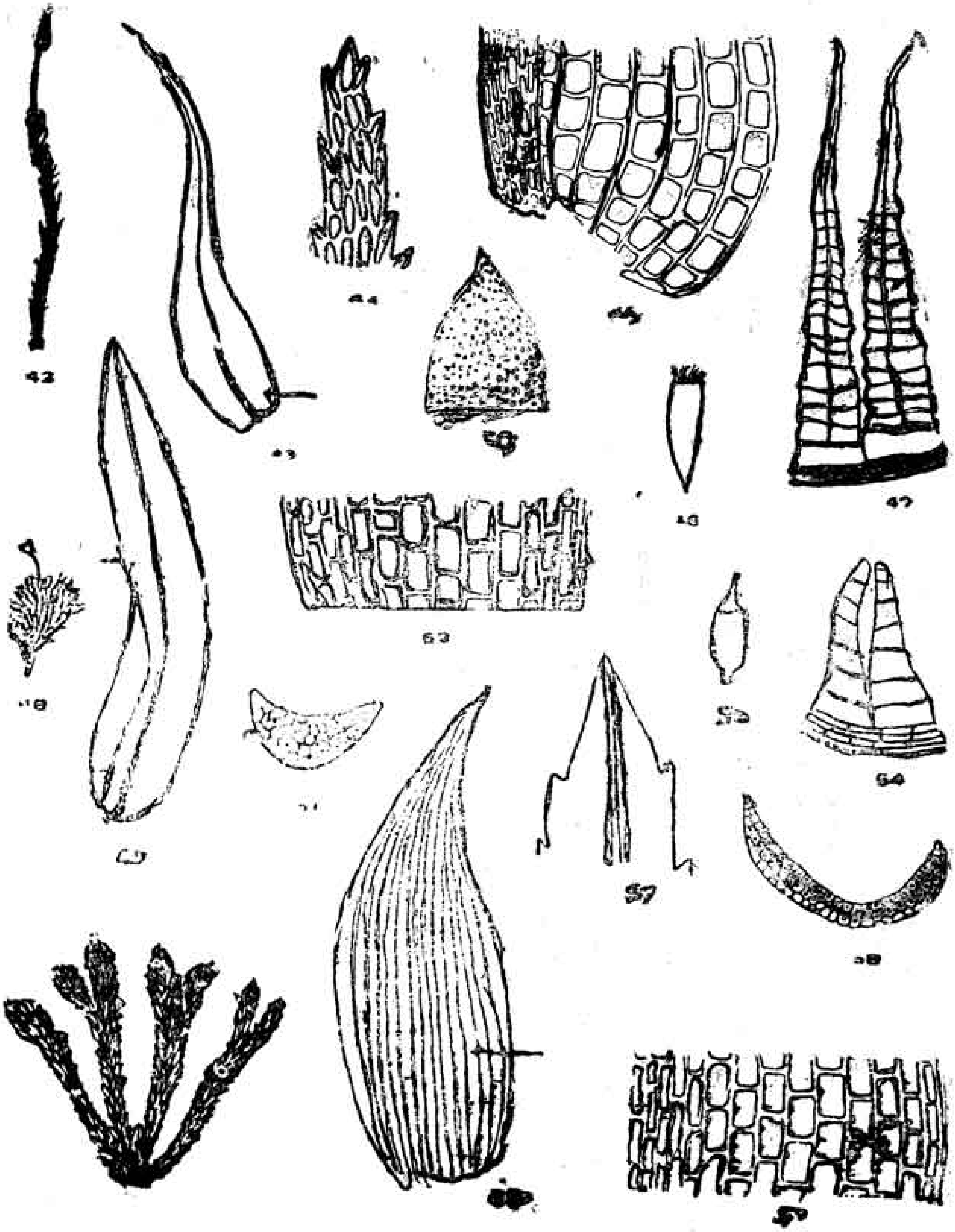


PLATE IV

Tortula muralis Hedw.

Figure 60. Showing plant with leaves and sporophyte. X 1

Figure 61. Showing plant with leaves and sporophyte. X 10

Figure 62. Leaf showing shape. X 20

Figure 63. Leaf showing apex. X 285

Figure 64. Cells of leaf. X 285

Figure 65. Capsule showing shape. X 20

Funaria hygrometrica Hedw.

Figure 66. Annulus. X 285

Tortula muralis Hedw.

Figure 67. Peristome. X 285 (Base and tip only shown)

Barbula indica Schw.

Figure 68. Showing plant with leaves and sporophyte. X 2

Figure 69. Showing plant with leaves and sporophyte. X 10

Figure 70. Leaf showing shape. X 40

Figure 71. Leaf showing apex. X 285

Figure 72. Cells of leaf. X 285

Figure 73. Gemmae detached. X 490

Figure 74. Capsule showing shape. X 20

Figure 75. Stoma with two guard cells. X 285

Figure 76. Guard cells of stoma divided by cross wall. X 285

Figure 77. Peristome. X 40

Figure 78. Peristome. X 60

PLATE IV

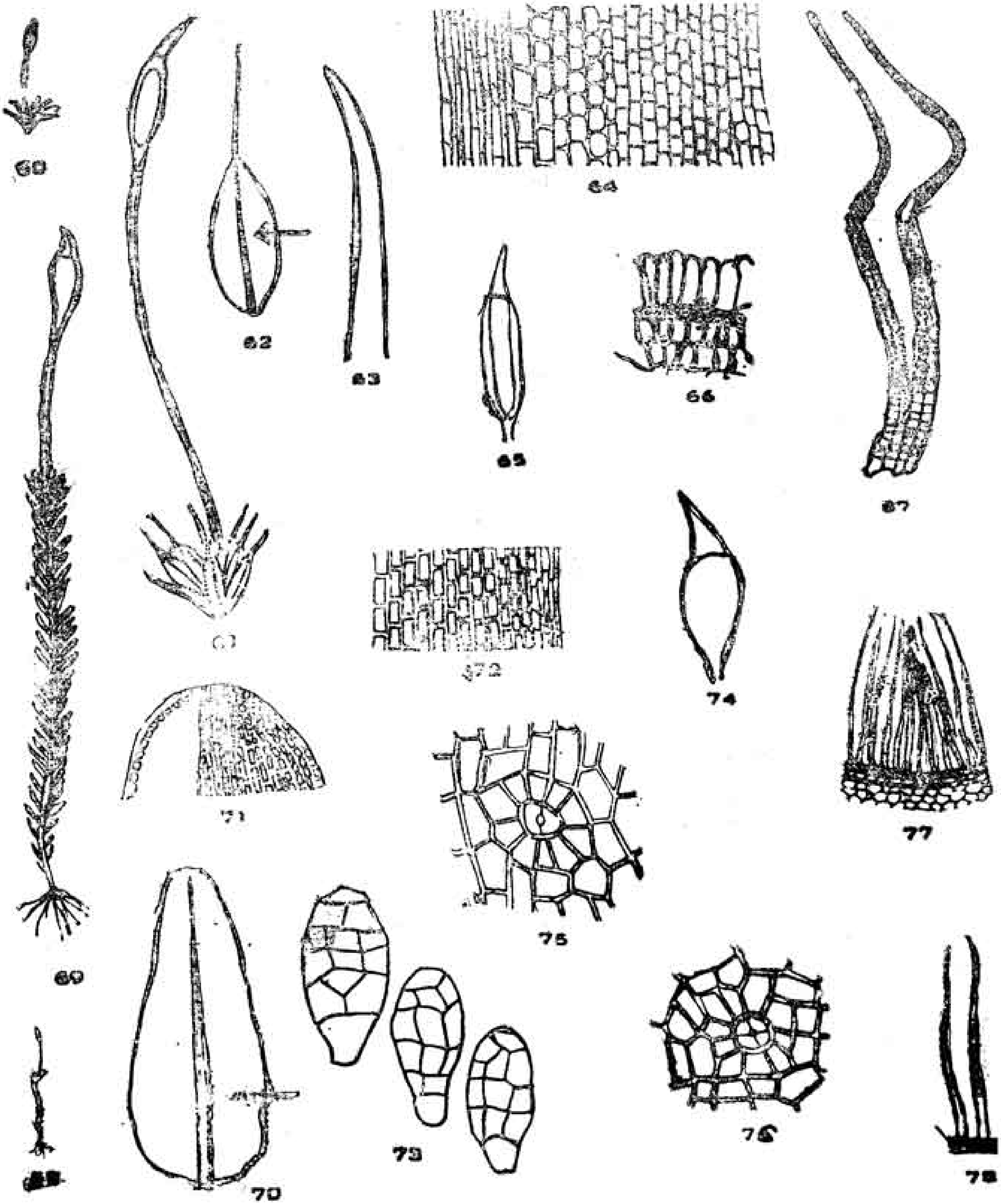


PLATE V

Trichostomum cylindricum (Bruch.) C.M.

Figure 79. Showing plant with leaves and sporophyte. X 2

Figure 80. Showing plant with leaves and sporophyte. X 10

Figure 81. Leaf showing shope. X 40

Figure 82. Leaf showing apex. X 285

Figure 83. Cells of leaf. X 285

Figure 84. Capsule showing shape. X 20

Figure 85. With annulus. X 285

Weisia macrospora Card.

Figure 86. Showing plant with leaves and sporophyte.

Figure 87. Showing plant with leaves and sporophyte.

Figure 88. Leaf showing shape. X 40

Figure 89. Leaf showing apex. X 285

Figure 90. Cells of leaf. X 285

Figure 91. Capsule showing shape. X 20

Hyophila involuta (Hook) Jaeg.

Figure 92. Showing plant with leaves and sporophyte. X 2

Figure 93. Showing plant with leaves and sporophyte. X 5

Figure 94. Leaf showing shape. X 40

Figure 95. Capsule showing shape X 20

Figure 96 Annulus in two rows. X 285

Figure 97. Leaf showing apex X 285

Figure 98. Cells of leaf. X 200

PLATE V

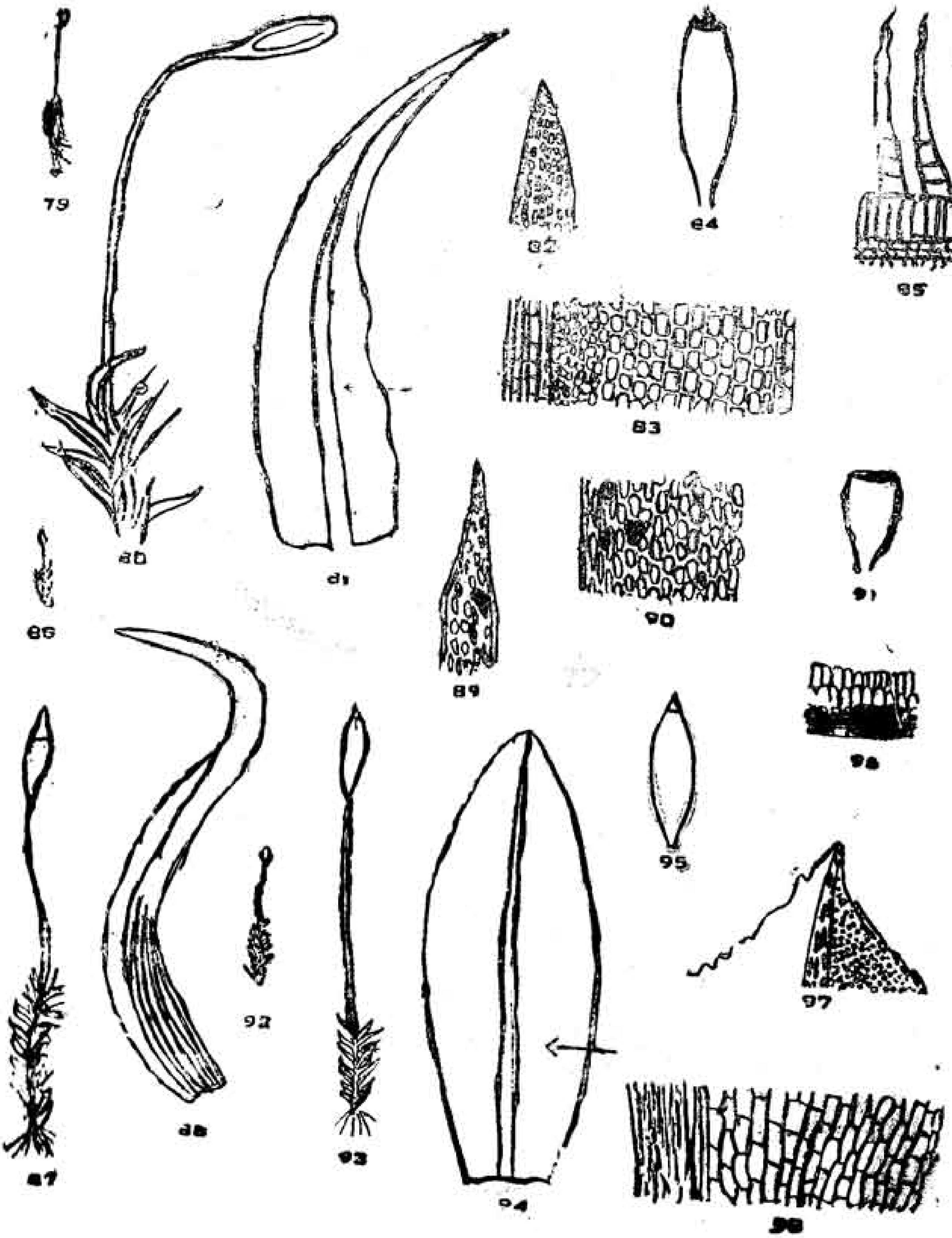


PLATE VI

Hyophila validinervis Card. and Vard.

Figure 99. Showing plant with leaves. X 2
Figure 100. Showing plant with leaves. X 10
Figure 101. Leaf showing shape. X 40
Figure 102. Leaf showing apex. X 285
Figure 103. Cells of leaf. X 40

Rhacomitrium javanicum Bryol.

Figure 104. Showing plant with leaves. X 2
Figure 105. Leaf showing apex. X 7
Figure 106. Leaf showing apex. X 285
Figure 107. Cells of leaf. X 285

Funaria hygrometrica Hedw.

Figure 108. Showing plant with leaves and sporophytes X 1
Figure 109. Leaf showing shape and margin. X 75
Figure 110. Leaf showing apex. X 75
Figure 111. Capsule showing apex. X 10

Tortula muralis Hedw.

Figure 112. Showing peristomial teeth twisted. X 128

Funaria hygrometrica Hedw.

Figure 113. Peristome. X 75
Figure 114. Peristome. X 285

PLATE VI

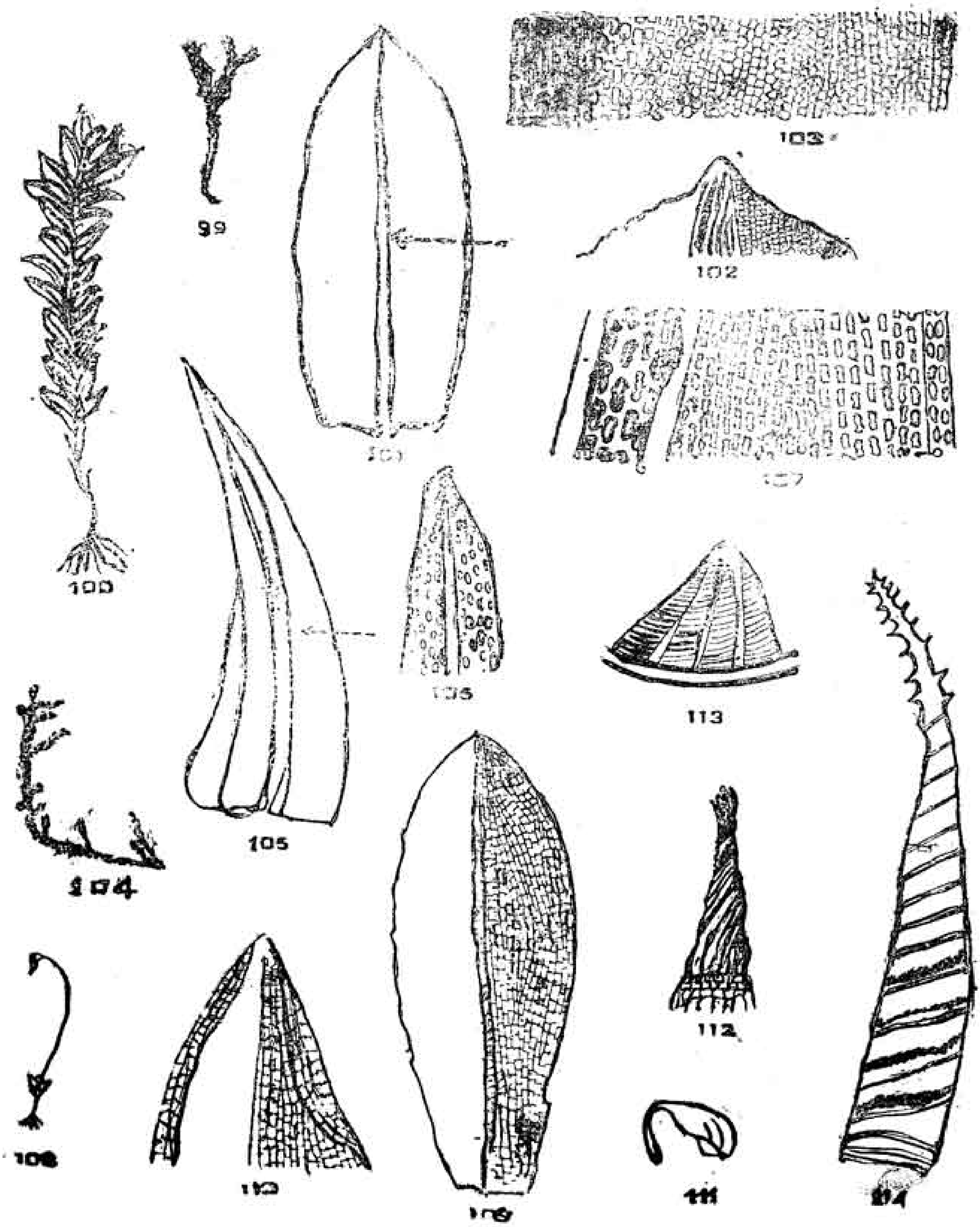


PLATE VII

Funaria submarginata Card. and Vard.

Figure 115. Showing plant with leaves and sporophyte. X 2

Figure 116. Showing plant with leaves and sporophyte. X 10

Figure 117. Leaf showing shape. X 20

Figure 118. Cells of leaf.. X 285

Figure 119. Capsule showing shape. X 20

Figure 120. Part of upper portion of capsule without peristome X 75

Pohlia flexuosa (Mitt.) Broth.

Figure 122. Showing plant with leaves and sporophyte. X 2

Figure 123. Showing plant with leaves and sporophyte. X 10

Figure 124. Leaf showing shape. X 40

Figure 125. Leaf showing apex. 285

Figure 126. Cells of leaf. X 285

Figure 127. Outer and inner peristome. X 285

PLATE VII

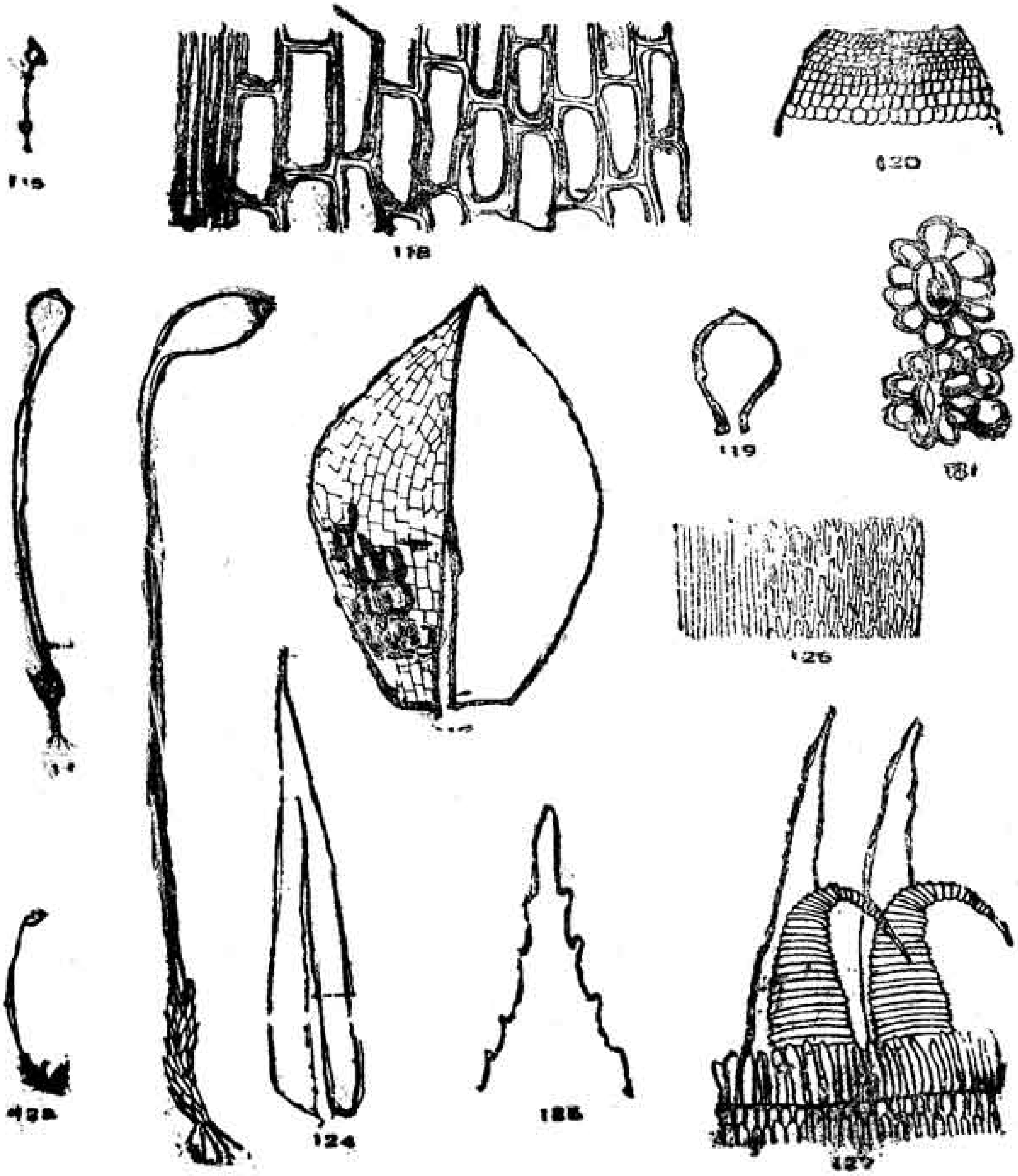


PLATE VIII

Brachymenium exile (Doz. and Molk.) Bryol.

Figure 128. Sohwing plant wlth leaves and sporophyte X 2

Figure 129. Showing plant with leaves and sporophyte. X 10

Figure 130 Leaf showing shape X 40

Figure 131. Cells of leaf. X 285

Figure 132 Peristome. X 128

Brachymenium leptostomoides (C. M.) Shimp.

Figure 133. Showing plant with leaves. X 2

Figure 134. Showing plant with leaves. X 10

Figure 135. Leaf showing shape. X 75

Figure 136. Leaf showing apex X 285

Figure 137. Cells of leaf. 285

Anomobryum subniditum Card. and Vard.

Figure 138. Showing plant with leaves and sporophpyte. X 2

Figure 139. Showing plant with leaves and sporophyte. X 10

Figure 140. Leaf showing shape. X 75

Figure 141. Peristome. X 285

Figure 142. Cells of leaf. X 285

Bryum argenteum Linn.

Figure 143. Showing plant with leaves and sporophyte. X 2

Figure 144. Showing plant with leaves and sporophyte. X 10

Figure 145. Leaf showing shape. X 75

Figure 146. Cells of leaf. X 285

Figure 147. Peristome. X 285

PLATE VIII

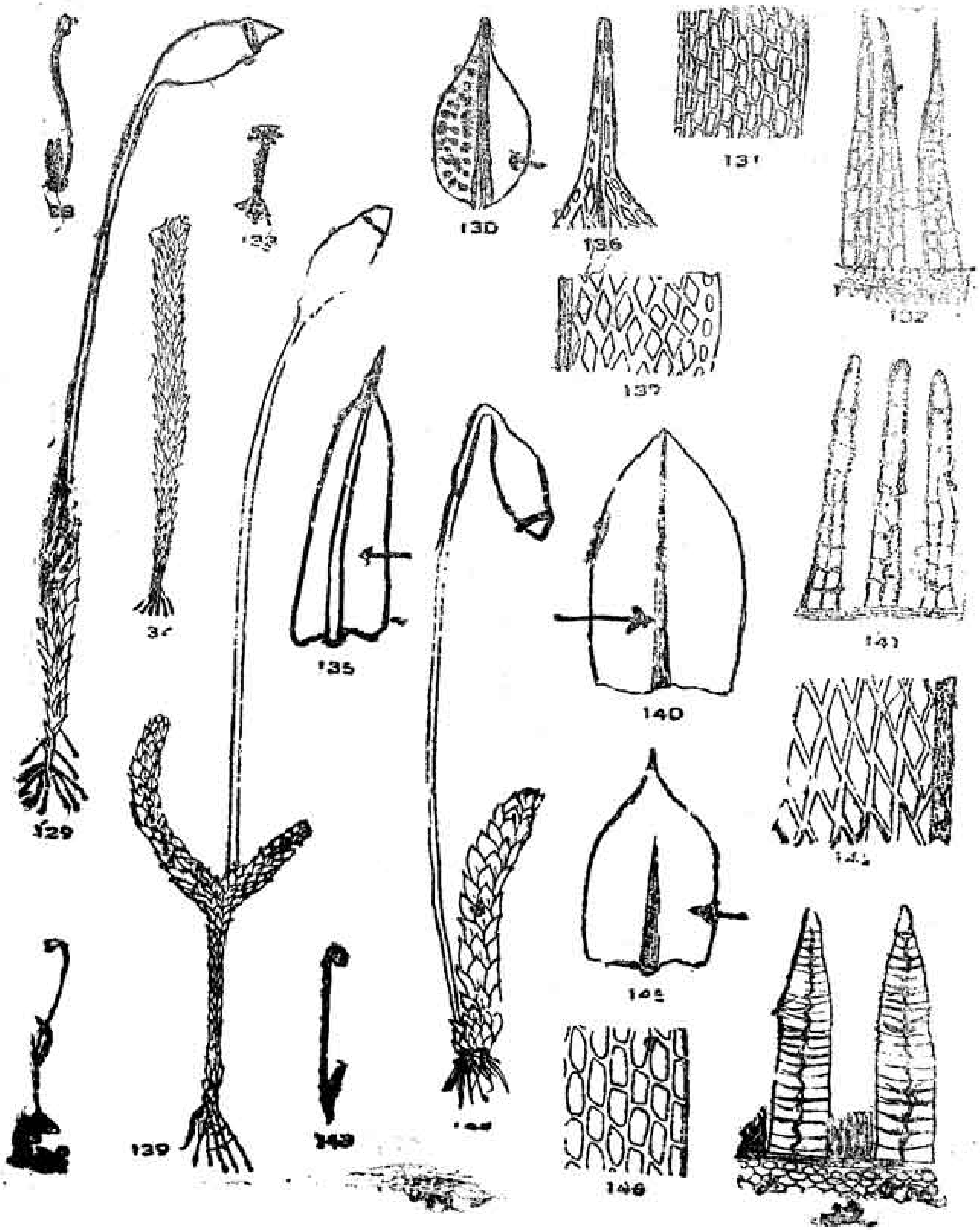


PLATE IX

Rhodobryum giganteum (Hook.) Par.

Figure 148: Showing plant with leaves and sporophyte. X 2

Figure 149. Leaf showing shape. X 10

Figure 150. Leaf showing apex. X 75

Figure 151. Capsule showing shape.X 5

Figure 152. Cells of leaf. X 285

Figure 153. Peristome X 285

Mnium coriaceum Griff.

Figure 154. Showing plant with leaves and sporophyte X 2

Figure 155. Leaf showing shape. X 20

Figure 156. Leaf showing apex. X 75

Figure 157. Cells of leaf. X 285

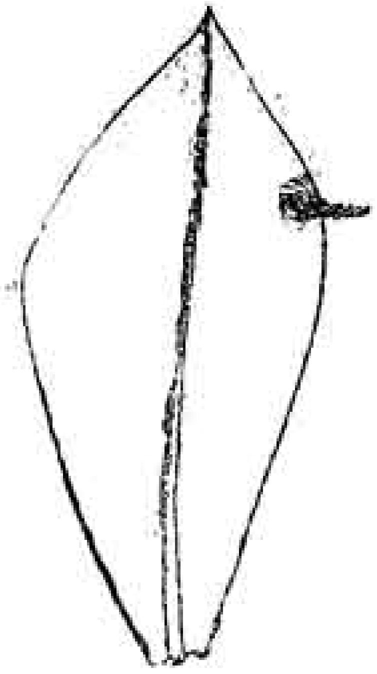
Figure 158. Capsule shape. X 20

Figure 159. Peristome. X 285

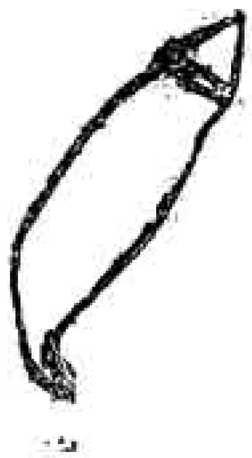
PLATE IX

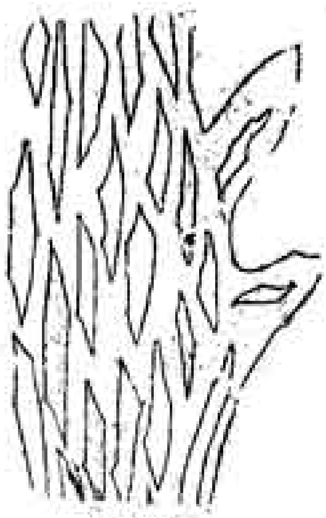


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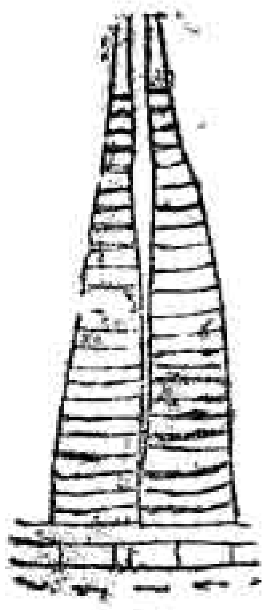


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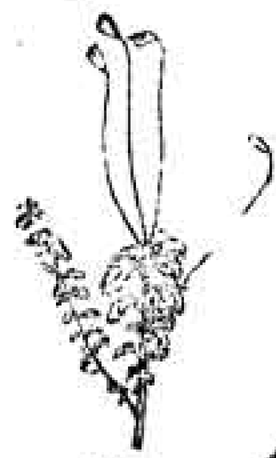




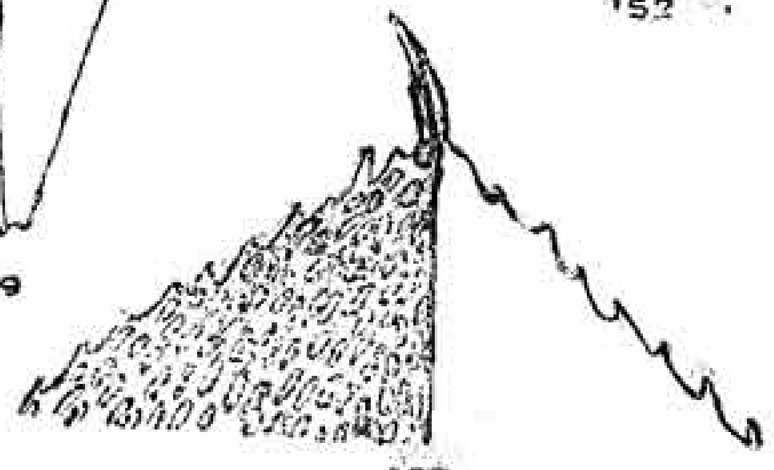
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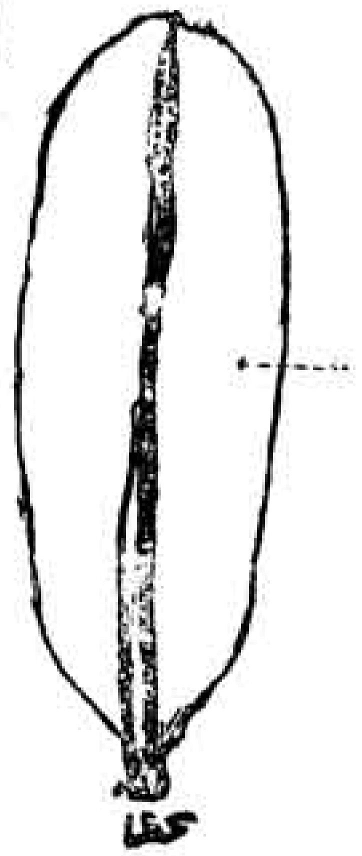
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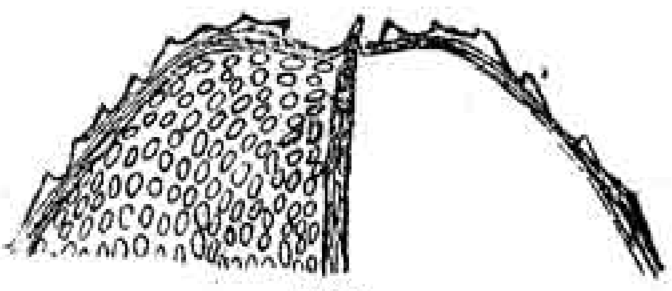
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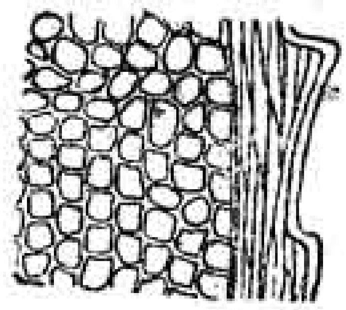
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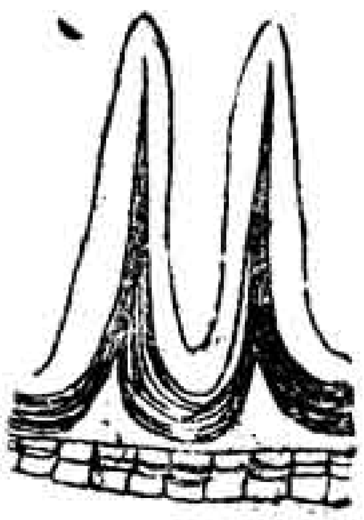
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PLATE X

Rhizogonium spiniforme (Hedw.) Bruch.

Figure 160. Showing plant with leaves and sporophyte. X 2

Figure 161. Leaf showing shape. X 20

Figure 162. Leaf showing apex. X 285

Figure 163. Cells of leaf. X 285

Figure 164. Capsule shape. X 20

Figure 165. Peristome. X 75

Figure 166. Inner peristome. X 75

Bartramia madurensis Dix. and Vard.

Figure 167. Showing plant with leaves. X 2

Figure 168. Leaf showing shape. X 40

Figure 169. Leaf showing apex. X 285

Figure 170. Cells of leaf. X 285

Philonotis anisoclada Card. and Vard.

Figure 171 Showing plant with leaves and sporophyte. X 2

Figure 172. Leaf showing shape. X 75

Figure 173. Leaf showing apex. X 285

Figure 174. Cells of leaf. X 285

Figure 175. Cells of leaf. X 750 (Note cellenchymatous thickening)

Figure 176. Capsule showing shape. X 20

Figure 177. Peristome. X 75

PLATE X

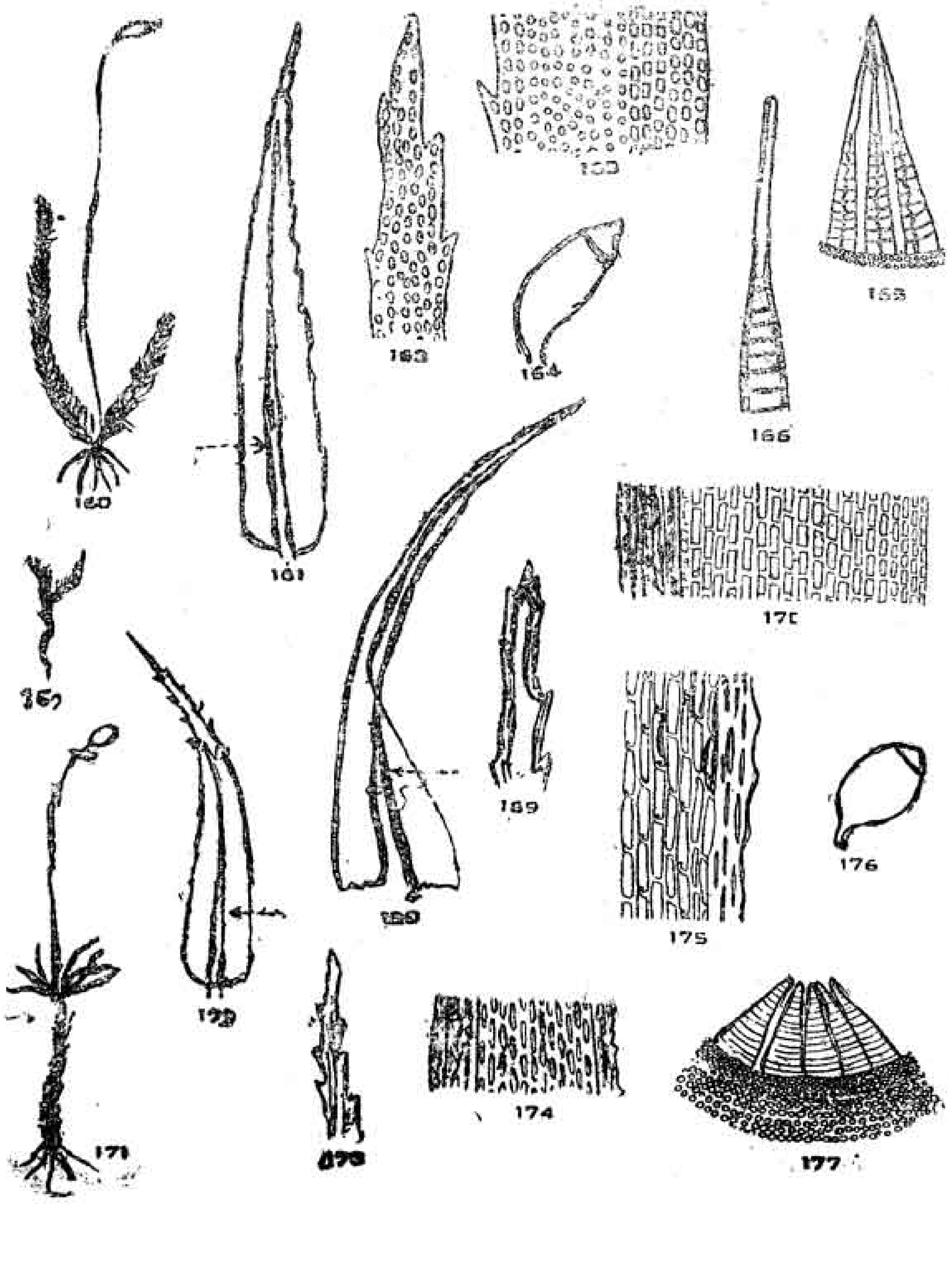


PLATE XI

Hypnodon perpusillus (Thw. and Mitt.) C.M.

Figure 178. Showing plant with leaves and sporophyte. X 2

Figure 179. Showing plant with leaves and sporophyte. X 25

Figure 180. Leaf showing shape. X 40

Figure 181. Cells of leaf. X 285

Figure 182. Leaf showing apex. X 75

Figure 183. Peristome. X 285

Schlotheimia grevilleana Mitt.

Figure 184. Showing plant with leaves and sporophyte. X 2

Figure 185 Showing plant with leaves and sporophyte. X 5

Figure 186. Leaf showing shape. X 75

Figure 187. Leaf showing apex. 75

Figure 188. Alar cells of leaf. X 285

Figure 189. Cells of leaf. X 285

Figure 190. Cells of upper leaf. X 285

Figure 191. Capsule showing shape. X 20

Figure 192. Peristome. X 285

PLATE XI

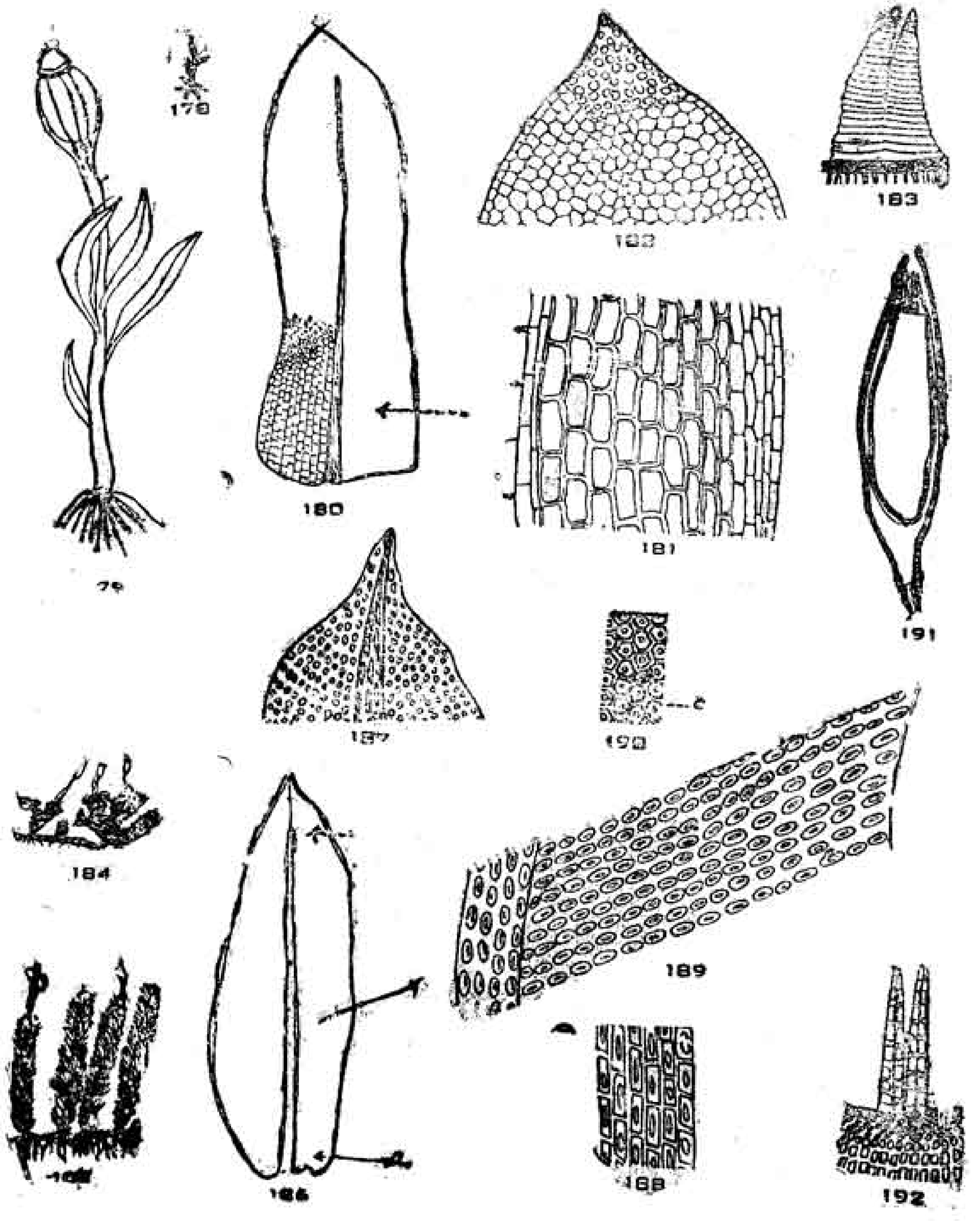


PLATE XII

Trachypus bicolor Rein. and Horns.

Figure 193. Showing plant with leaves. X 2
Figure 194. Leaf showing shape. X 75
Figure 195. Leaf showing apex. X 285
Figure 196. Cells of leaf. X 285
Figure 197. Cells of leaf. X 750.

Trachypus humilis Lind. var *humilis* Zanten.

Figure 198. Showing plant with leaves. X 2
Figure 199. Leaf showing shape, without costa. X 75
Figure 200. Leaf showing apex. X 285
Figure 201. Cells of leaf. X 750
Figure 202. Alar cells of leaf. X 285
Figure 203. Cells of upper leaf. X 285

Trachypodopsis serrulata (Beauv.) Fleis. var. *crispatula* (Hook.) Zanten.

Figure 204. Showing plant with leaves. X 2
Figure 205. Leaf showing apex. X 30
Figure 206. Leaf showing apex. X 285
Figure 207. Cells of leaf. X 285
Figure 208. Cells of leaf. X 750
Figure 209. Alar cells of leaf. X 750

PLATE XII

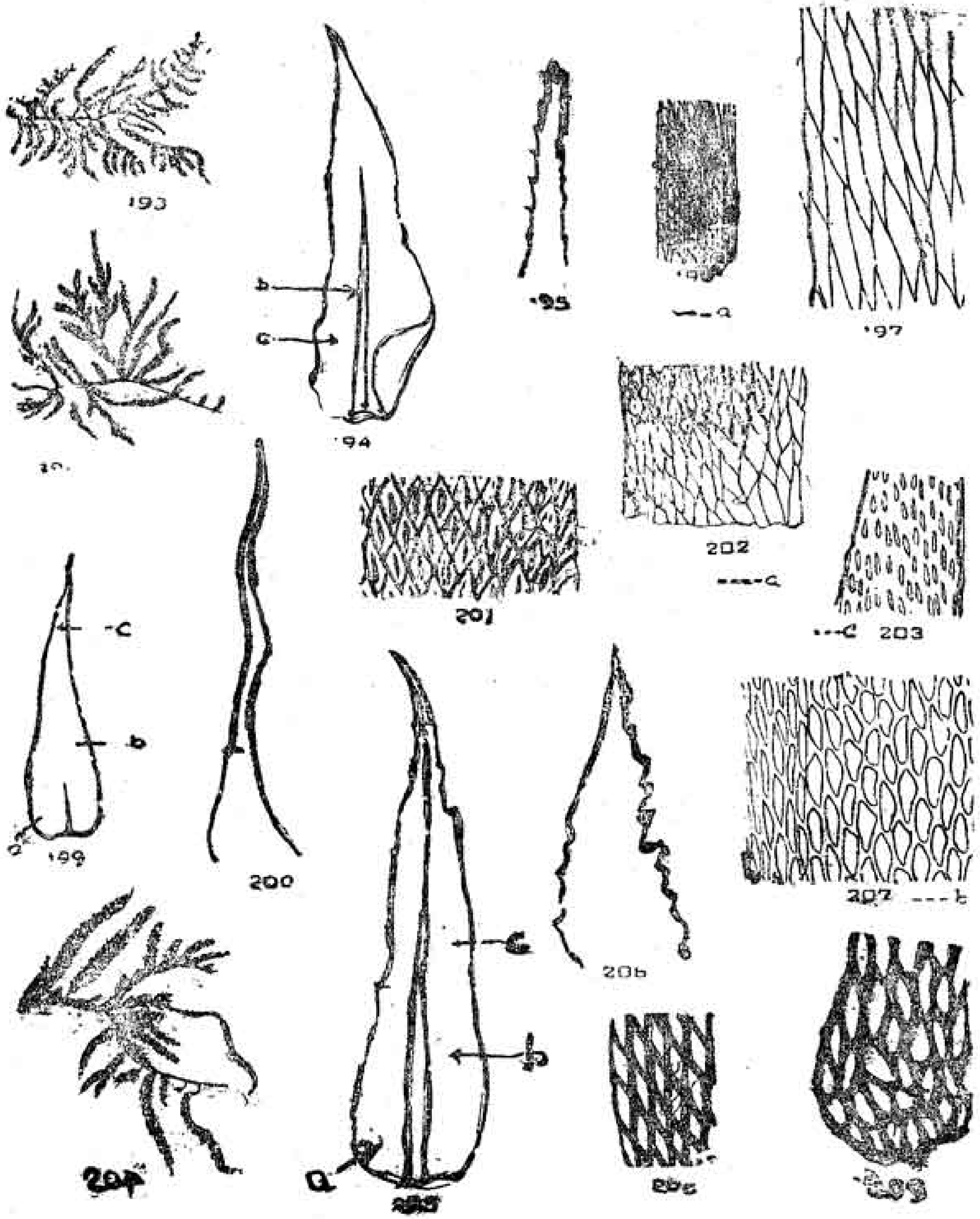


PLATE XIII

Myurium warburgii (C. M.) Fleis.

Figure 210. Showing plant with leaves. X 2
Figure 211. Leaf showing shape. X 30
Figure 212. Leaf showing apex. X 285
Figure 213. Cells of upper leaf. X 285
Figure 214. Cells of lower leaf. X 285

Pterobryopsis orientalis (C. M.) Fleis.

Figure 15. Showing plant with leaves. X 2
Figure 216. Leaf showing shape. X 75
Figure 217. Leaf showing apex. X 285
Figure 218. Alar cells of leaf. X 285

Papillaria crocea (Hamp.) Jaeg.

Figure 219. Showing plant with leaves. X 2
Figure 220. Leaf showing shape. X 75
Figure 221. Leaf showing apex. X 285
Figure 222. Cells of leaf. X 285

Aerobryopsis longissima (Doz. and Molk.) Fleisch.

Figure 223. Showing plant with leaves. X 2
Figure 224. Leaf showing shape. X 20
Figure 225. Leaf apex. X 75
Figure 226. Cells of leaf. X 285

PLATE XIII

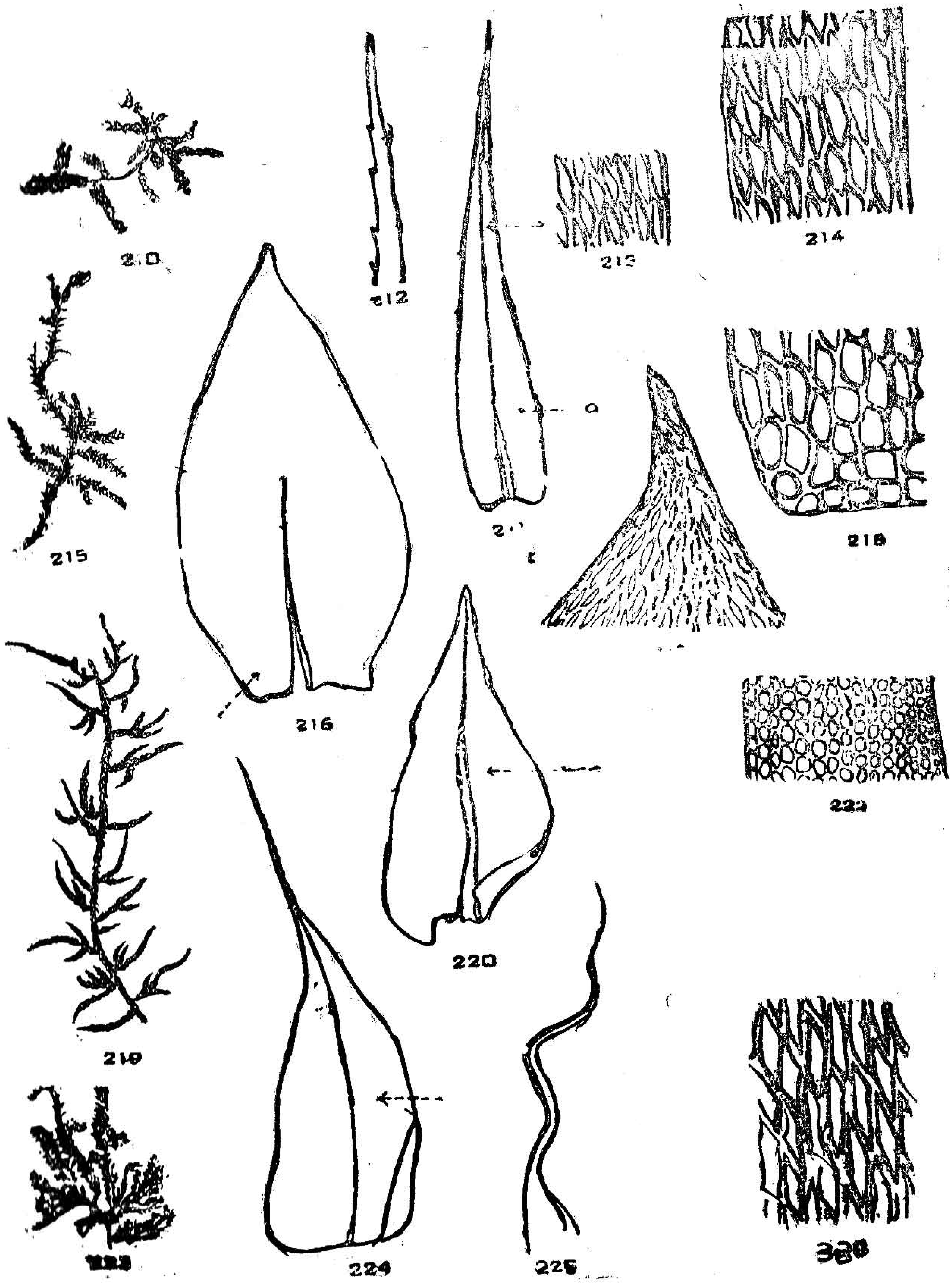


PLATE XIV

Barbella tenax (C. M.) Broth.

Figure 227. Showing plant with leaves. X 2
Figure 228. Leaf showing apex. X 285
Figure 229. Leaf showing shape. X 75
Figure 230. Cells of leaf. X 750

Barbella determessi (Rein. and Card.) Fleish.

Figure 231. Showing plant with leaves. X 2
Figure 232. Leaf showing shape. X 40
Figure 233. Leaf showing apex. X 285
Figure 234. Cells of leaf. X 750

Barbella pendula (Sull.) Fleisch.

Figure 235. Showing plant with leaves. X 2
Figure 236 Leaf showing shape. X 75
Figure 237. Leaf showing apex. X 285
Figure 238. Cells of leaf. X 750

Floribundaria floribunda (Doz. and Molk.) Fleisch.

Figure 239. Showing plant with leaves. X 2
Figure 240. Leaf showing shape. X 75
Figure 241. Leaf showing apex. X 285
Figure 242. Cells of leaf. X 750.

PLATE XIV

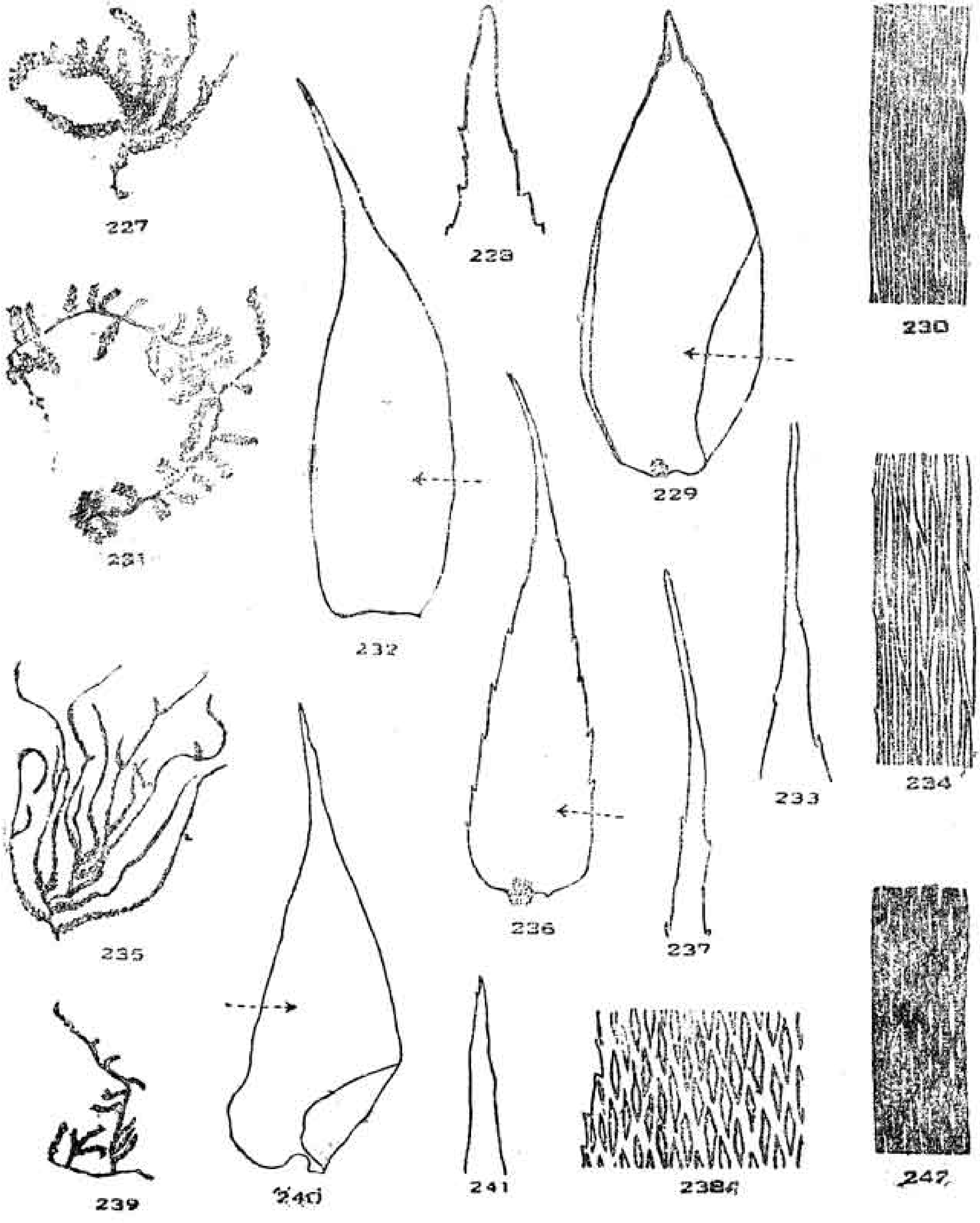


PLATE XV

Meteoriopsis squarrosa (Hook .) Fleisch.

Figure 243. Showing plant with leaves. X 2
Figure 244. Leaf showing shape. X 20
Figure 245. Leaf showing apex. X 285
Figure 246. Cells of leaf. X285

Meteoriopsis reclinata (C. M.) Fleisch.

Figure 247. Showing plant with leaves. X 2
Figure 248. Leaf showing shape. X 75
Figure 249. Leaf showing apex. X 285
Figure 250. Cells of leaf. X 750

Homaliodedrn exiguum (Bryol. Jav.) Fleisch.

Figure 251. Showing plant with leaves. X 2
Figure 252. Leaf showing shape. X 75
Figure 253. Cells of leaf. X 750

Homaliodendron flabellatum (Dix. Sm.) Fleisch.

Figure 254. Showing plants ·with leave. X 2
Figure 255. Leaf showing shape and apex. X 75
Figure 256. Cells of leaf. X 750

PLATE XV

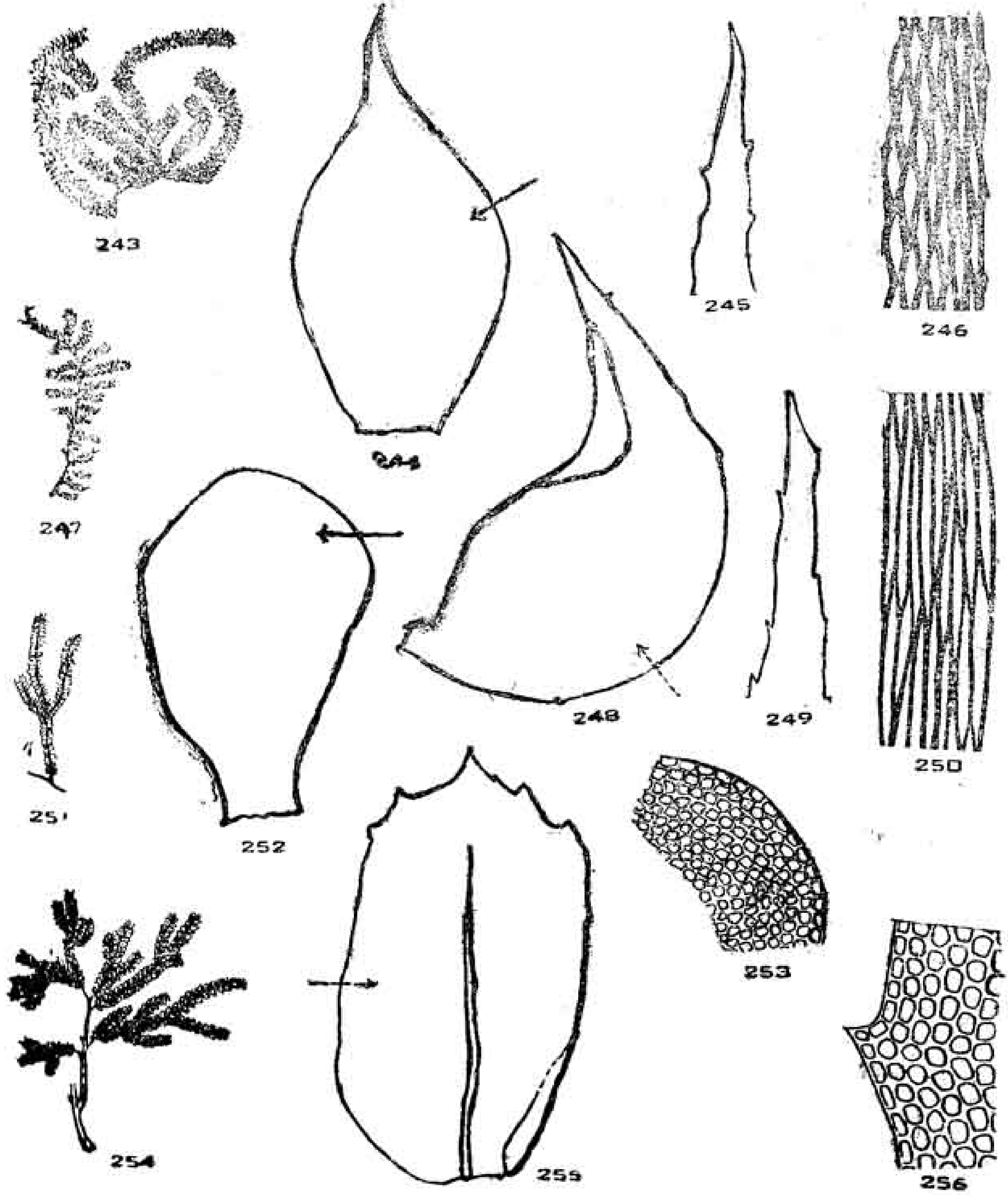


PLATE XVI

Distichophyllum succulentum (Mitt.) Broth.

Figure 257. Showing plant with leaves. X 2
Figure 258. Leaf showing shape. X 75
Figure 259. Leaf showing apex X 285
Figure 260. Cells of leaf. X 285

Hookeria acutifolia Hook.

Figure 261. Showing plant with leaves. X 2
Figure 262. Leaf showing shape. X 40
Figure 263. Leaf showing apex. X 285

Hypopterygium tenellum Lac. = H. *ceylonicum Mitt.*

Figure 264. Showing plant with leaves. X 2
Figure 265. Leaf showing shape. X 75
Figure 266. Cells of leaf. X 285

Rhegmatodon orthostegius Mont.

Figure 267. Leaf showing apex. X 285
Figure 268. Showing plant with leaves and sporophyte. X2
Figure 269. Leaf showing shape. X 75
Figure 271. Capsule showing shape. X 20
Figure 270. Cells of leaf. X 750
Figure 272. Apophysis showing stomata. X 275
Figure 273. Inner peristome. X285
Figure 274- Peristome. X 285

PLATE XVI

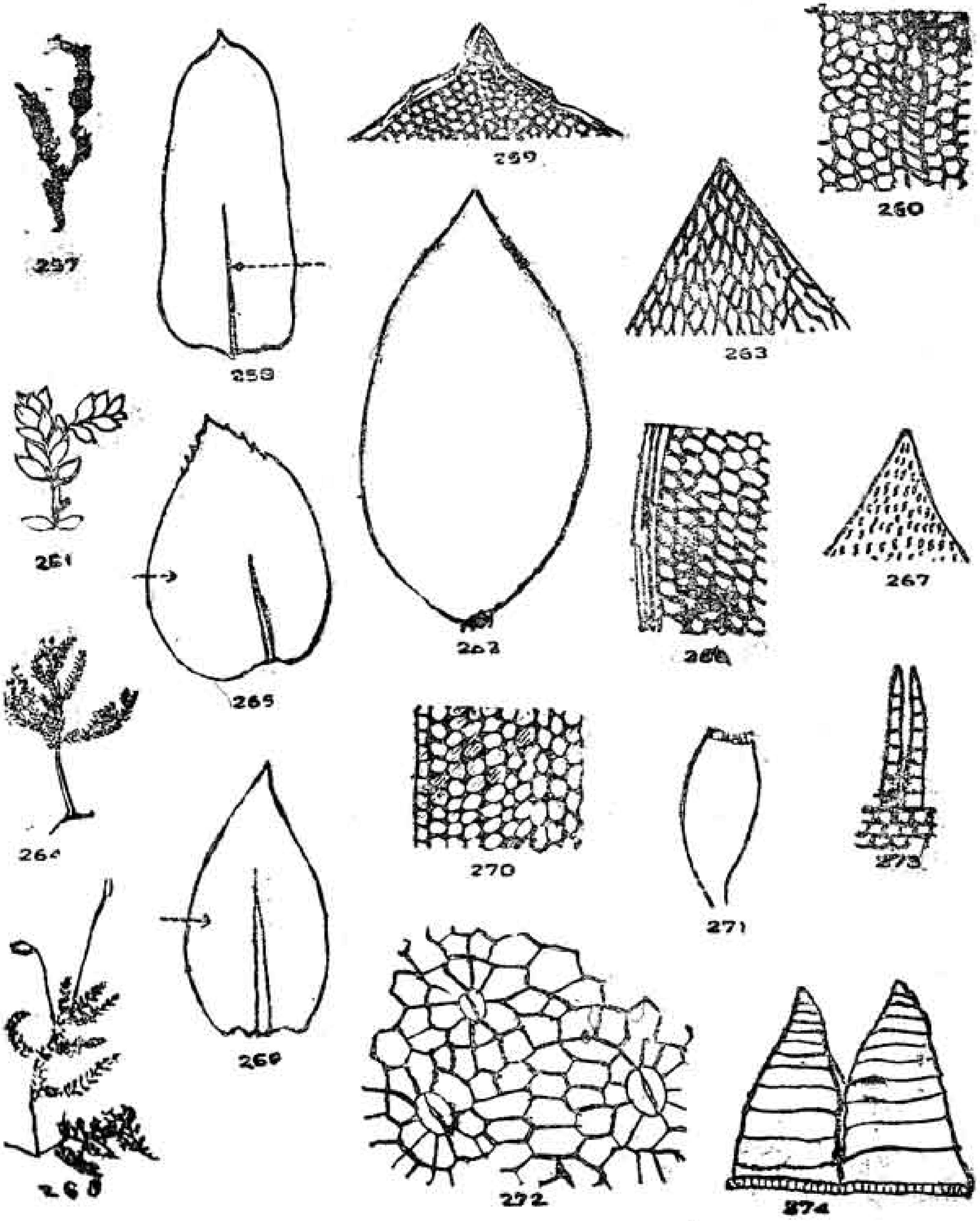

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PLATE XVII

Herpetineurum toccoae (Sull. and Lesq.) Card.

Figure 275. Showing plant with leaves. X 2
Figure 276. Leaf showing shape. X 75
Figure 277. Leaf showing apex. X 750
Figure 278. Cells of leaf. X 750

Thuidium tamariscellum (C. M) Bryol. Jav.

Figure 279. Showing branch with leaves and sporophyte. X 2
Figure 280. Branch leaf showing shape. X 75
Figure 281. Branch leaf showing apex. X 285
Figure 282. Stem leaf showing shape. X 75
Figure 283. Stem leaf showing apex. 285
Figure 284. Cells of branch leaf. X 750
Figure 285. Capsule showing shape. X 20
Figure 286. Peristome. X 285
Figure 287. Alar cells of stem leaf. X 750

Pleuropus nilghiriense (Mont.) Toyama

Figure 288. Showing branch with leaves and sporophyte. X 2
Figure 289. Leaf showing shape. X 75
Fignre 290. Leaf showing apex. X 285
Figure 291. Cells of leaf. X 750
Fignre 292. Capsule showing shape. X 20
Figure 293. Peristome. X 285

PLATE XVII

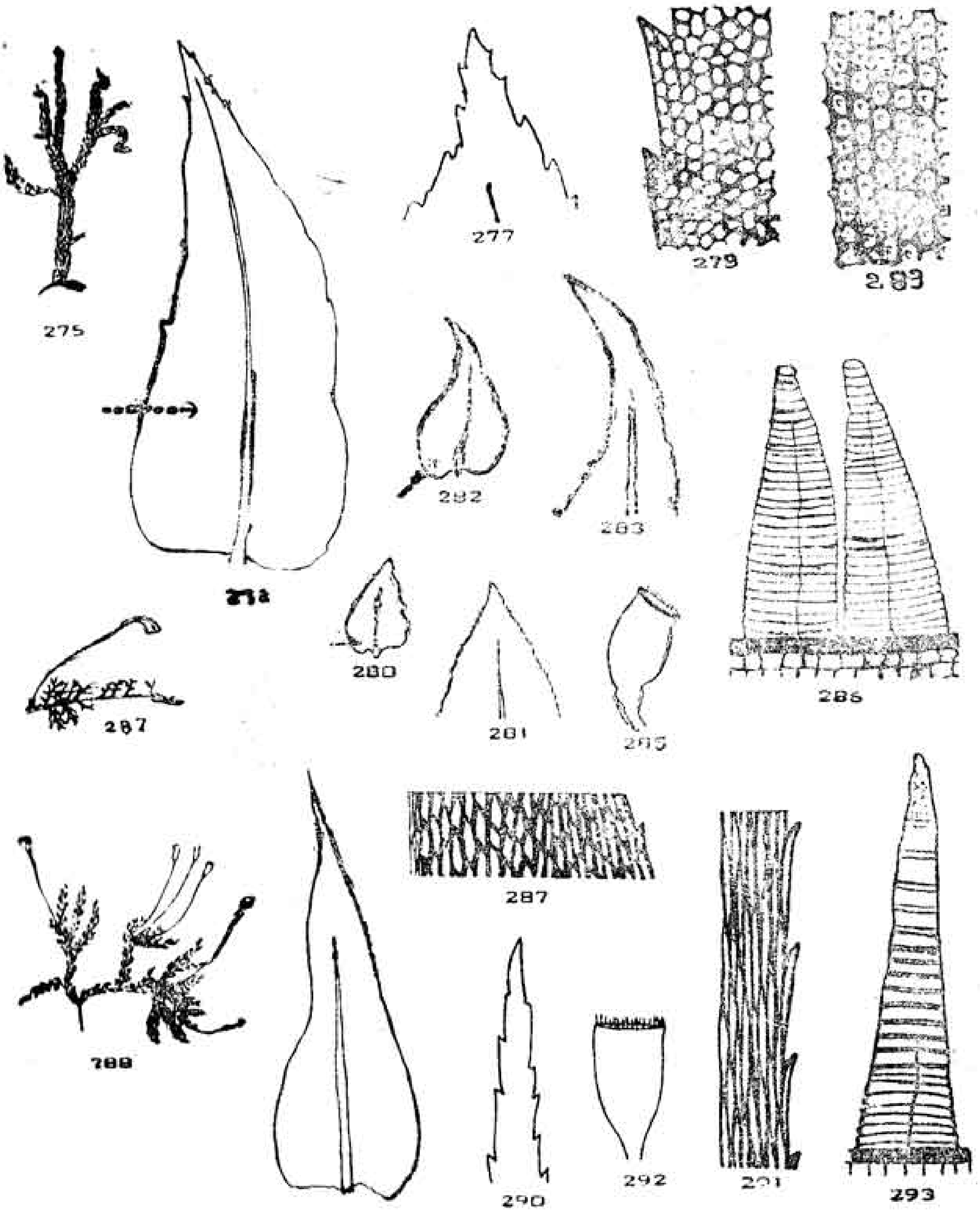


PLATE XVIII

Rhynchostegium javanicum (Bel.) Besch.

Figure 294. Showing branch with leaves and sporophyte. X 2.
Figure 295. Leaf showing shape. X 20
Figure 296. Leaf showing apex. X 285
Figure 297. Cells of leaf. X 750
Figure 298. Capsule showing shape. X 20
Figure 299. Peristome. X 285

Erythrodontium julaceum (Hook.) Par.

Figure 300. Showing branch with leaves and sporophyte.
Figure 301. Leaf showing shape. X 75
Figure 302. Leaf showing apex. X 285
Figure 303. Cells of lower leaf. X 750
Figure 304. Cells of upper leaf. X 750
Figure 305. Capsule showing shape. X 20
Figure 306. Peristome. X 285

PLATE XVIII

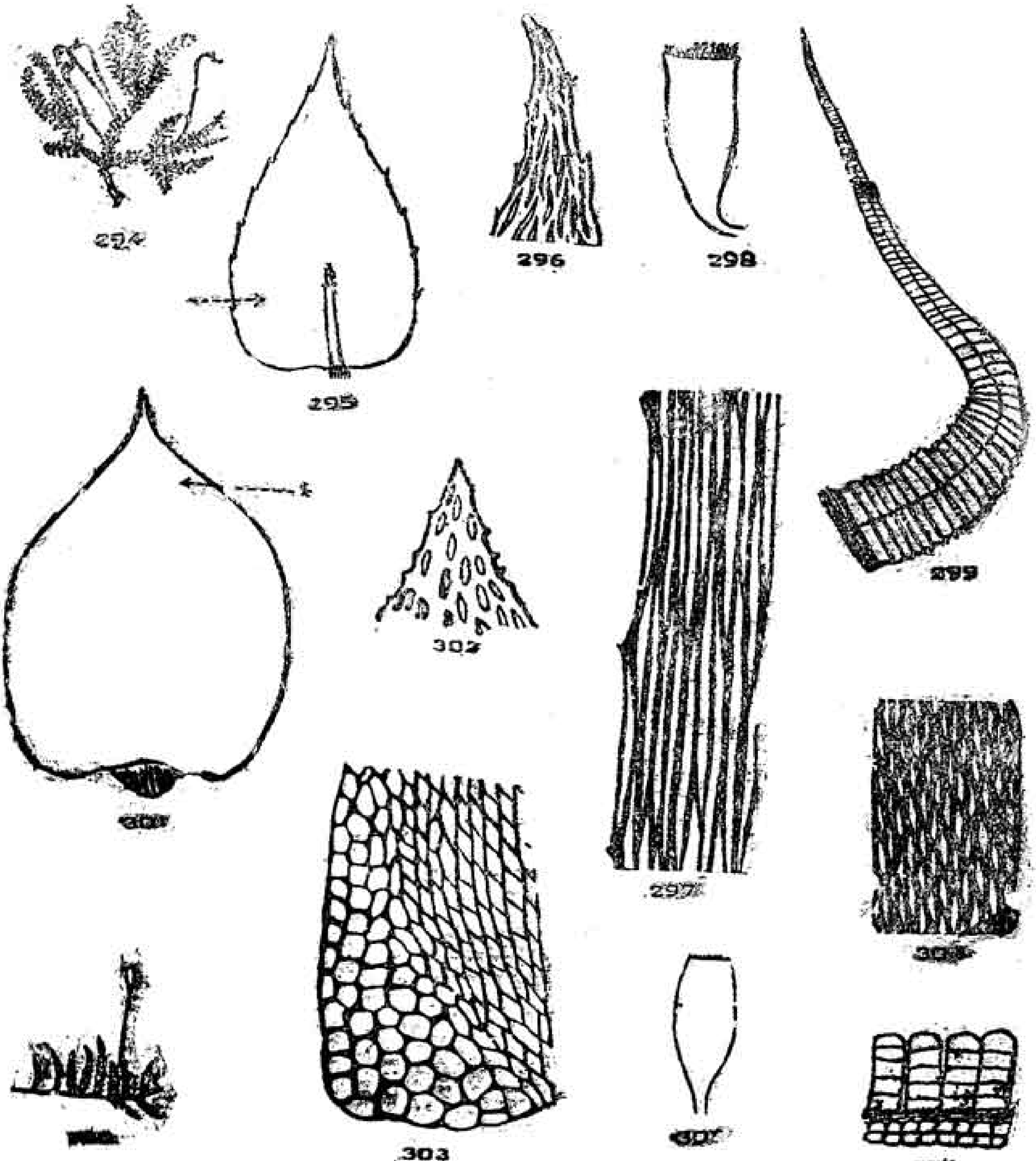


PLATE XIX

Foreauella indica Dix. and Vard.

Figure 307. Showing branch of plant with leaves. x 2.
Figure 308. Leaf showing shape. X 75
Figure 309. Alar cells of leaf. X 750
Figure 310. Leaf showing apex. X 285

Sematophyllum subhumile (C.M.) Fleisch.

Figure 311. Showing branch of plant with leaves and sporophyte. X 2.
Figure 312. Leaf showing shape. X 75
Figure 313. Cells of leaf. X 750
Figure 314. Cells of upper leaf. X 750
Figure 315. Capsule showing shape. X 20
Figure 316 Peristome. X 285

Warburgiella leptorrhynchoides (Mont.) Fleisch.

Figure 317. Showing plant with leaves. X 2
Figure 318. Leaf showing shape. X 75
Figure 319. Leaf showing apex. X 285
Figure 320. Cells of leaf. X 750

Hypnum cupressiforme Hedw.

Figure 321. Showing plant wiih leaves. X 2
Figure 322. Leaf showing shape. X 285
Figure 323. Leaf showing apex. X 285
Figure 324. Cells of leaf. X 750

PLATE XIX

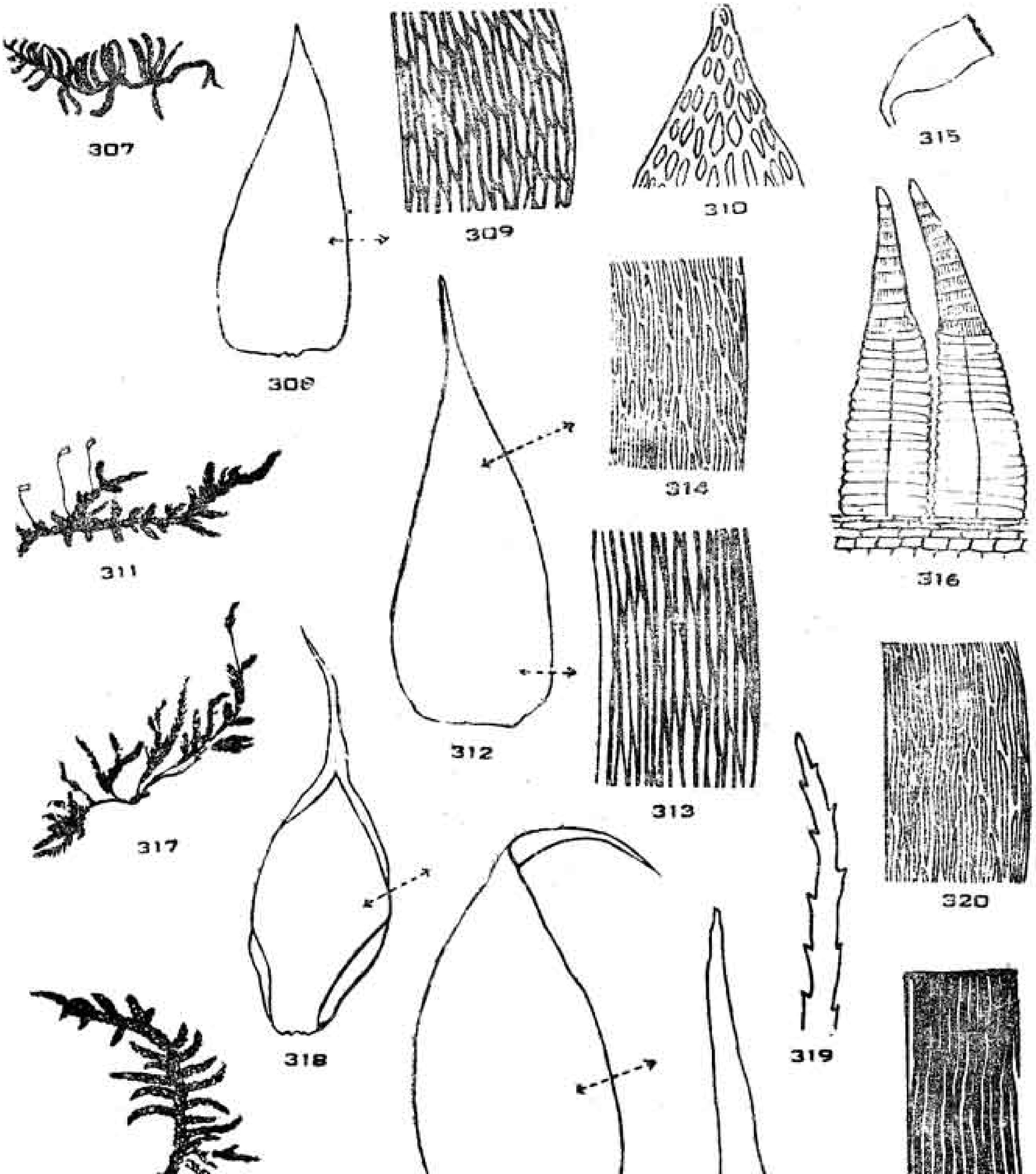

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PLATE XX

Taxiphyllum taxirameum (Mitt.) Fleisch.

Figure 325. Showing plant with leaves. X 2
Figure 326. Leaf showing shape. X 75
Figure 327. Leaf showing apex. X 285
Figure 328. Cells of leaf. X 750

Ctenidium lychnites (Mitt.) Broth.

Figure Showing branch of plant with leaves and sporo phyte. X 2
Figure 330. Leaf showing apex. X 75
Figure 331. Leaf showing apex. X 285
Figure 332. Cells of leaf. X 750
Figure 333. Capsule showing shape. X 20
Figure 334. Peristome. X 75
Figure 335. Peristome. X 285

Artichum aculeatum Card. and Vard.

Figure 336. Showing plant with leaves and sporophyte. X 2
Figure 337. Leaf showing shape. X 20
Figure 338. Cells of leaf. X 285
Figure 339, Cells of upper leaf. X 750
Figure 340. Capsule showing shape. X 20
Figure 341. Peristome. X 285

PLATE XX

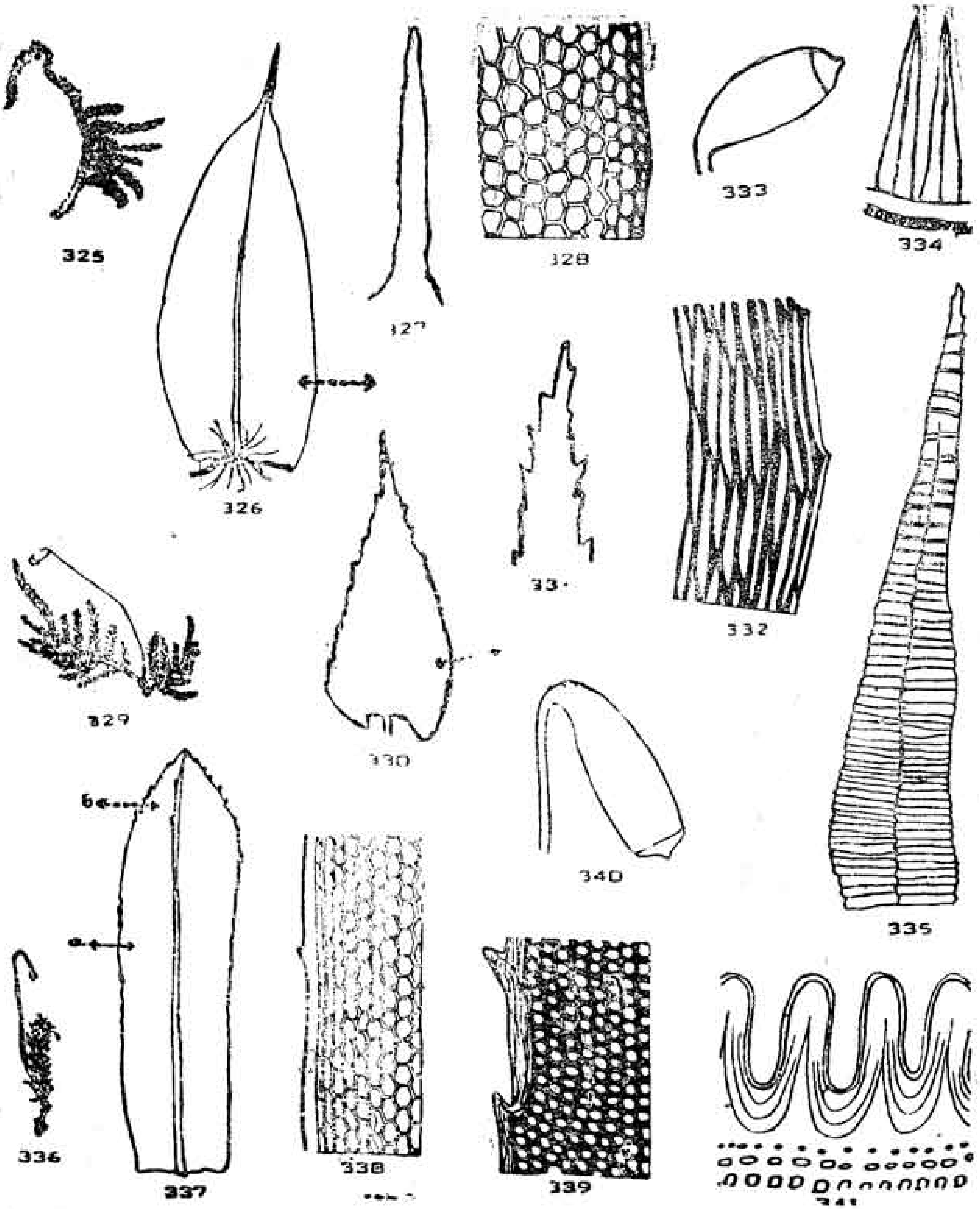


PLATE XXI

Pogonatum microstomum (R. Br.) Brid.

Figure 342. Showing plant with leaves and sporophyte. X 2
Figure 343. Leaf showing shape. X 15
Figure 344. Leaf showing apex X 285
Figure 345. Alar cells of leaf. X 285
Figure 346. Capsule showing shape. X 20
Figure 347. Peristome. X75
Figure 348. Peristome. X 285
Figure 349. Transverse section of leaf. X 75

Pogonatum neesii (C. M.) Mitt.

Figure 350. Showing plant with leaves and sporophyte. X 2
Figure 351. Leaf showing shape. X 15
Figure 352. Leaf showing apex. X 285
Figure 353. Alar cells of leaf. X 285
Figure 354. Transverse section of leaf. X 285
Figure 355. Capsule showing shape. X 20
Figure 356. Peristome. X 285

PLATE XXI

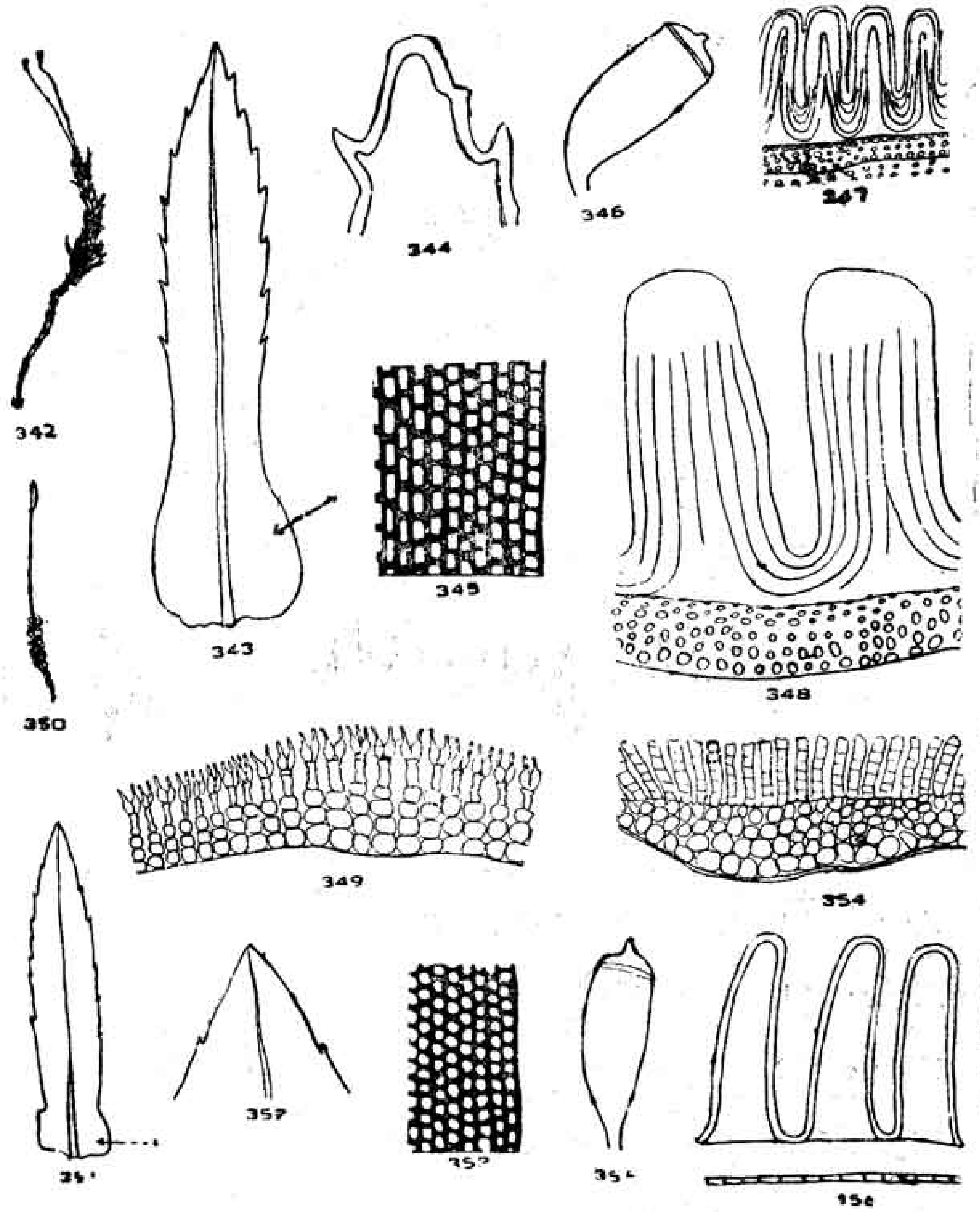


PLATE XXII

Figure 357. Operculum of *Fissidens schimidii* C. M X 75

Figure 358. Operculum of *Ditrichum amoenum* (Thw. and Mitt.) Par. X 75

F gure 359. Operculum of *Trematodon ceylonensis* C. M. X 75

Figure 360. Operculum of *Campylopus nodiflorus* (C M.) Jaeg. X 75

Figure 361. Operculum *Dicranodontium fragile* (Hook.) Broth. X 75

Figure 362. Operculum of *Leucobryum neilgherrense* C. M. X 75

Figure 363. Operculum of *Tortula muralis* Hedw. X 75

Figure 364. Operculum of *Barbula indica* (Schw.) Brid. X 75

Figure 365. Operculum of *Trichostomum cylindricum* (Bruch.) C. M. X 75

Figure 366. Operculum of *Weisia macrospora* Card. X 75

Figure 367. Operculum of *Hyophila involuta* (Hook.) Jaeg. X 75

Figure 368. Operculum of *Funaria hygrometrica* Hedw X 75

Figure 369. Operculum of *Funaria submarginata* Card. and Vard. X 75

Figure 370. Operculum of *Pohlia flexuosa* (Mitt.) Broth. X 75

Figure 371. Operculum of *Brachymenium exile* (Doz. and Molk.) Bryol. X 75

Figure 372. Operculum of *Anomobryum subniditum* Card and Vard. X 75

Figure 373. Operculum of *Bryum argenteum* Linn. X 75

PLATE XXII

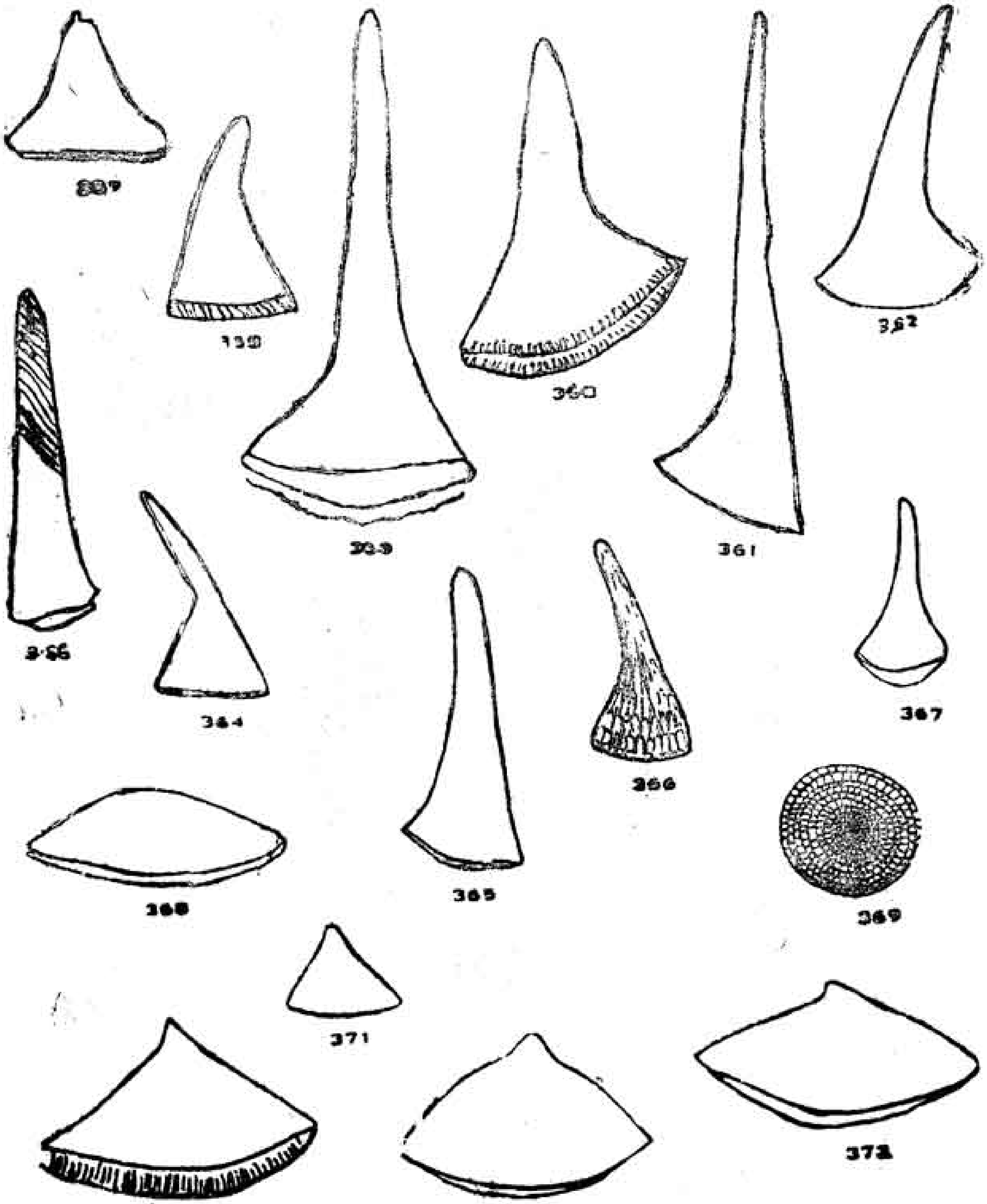


PLATE XXIII

Figure 374. Operculum of *Rhodobryum giganteum* (Hook.) Par. X 75

Figure 375. Operculum of *Rhizogonium spiniforme* (Hedw). Bruch. X 75

Figure 376. Operculum of *Philonotis anisoclada* Card. and Vard. X 75

Figure 377. Operculum of *Hypnodon perpusillus* (Thw. and Mitt. C.M. X 75

Figure 378. Operculum of *Papillaria crocea* (Hamp.) Jaeg. X 75

Figure 379. Operculum of *Rhegmatodon orthostegius* Mont. X 75

Figure 380. Operculum of *Thuidium tamariscellum* (C.M.) Bryol. Jav. X 75

Figure 381. Operculum of *Rhynchostegium javanicum* (Bel.) Besch. X 75

Figure 382. Operculum of *Sematophyllum subhumile* (C.M.) Fleich. X 75

Figure 383. Operculum of *Ctenidium lychnites* (Mitt.)

Figure 384. Operculum of *Atrichum aculeatum* Card and Vard. X 75

Figure 385. Operculum of *Pogonatum neesii* (C.M.) Mitt. X 75

PLATE XXIII

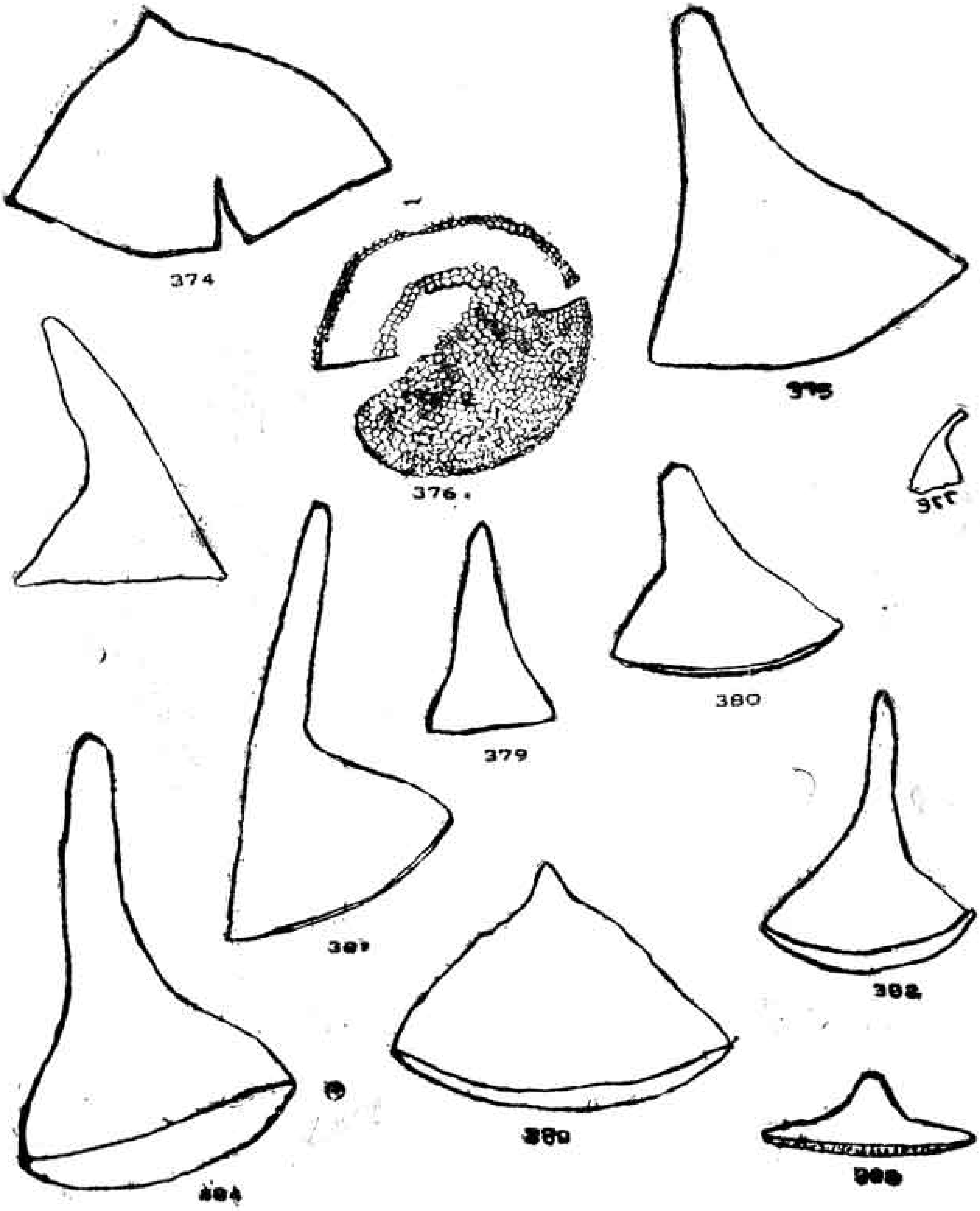


PLATE XXIV

Figure 386. Spores of *Fissidens schimidii* C.M. X 750
Figure 387. Spores of *Ditrichum amoenum* (Thw. and Mitt.) Par. X 750
Figure 388. Spores of *Trematodon ceylonensis* C.M. X 750
Figure 389. Spores of *Campylopus nodiflorus* (C.M.) Jaeg. X 750
Figure 3 0. Spores of *Leucobryum neilgherrense* C.M. X 750
Figure 391. Spores of *Dicranodontium fragile* (Hook.) Broth. X 750
Figure 392. Spores of *Trichostomum cylindricum* (Bruch.) C.M. X 750
Figure 393. Spores of *Barbula indica* (Schw.) Brid. X 750
Figure 394. Spores of *Tortula muralis* Hedw. X 750
Figure 395. Spores of *Funaria hygrometrica* Hedw. X 750
Figure 396. Spores of *Funaria submarginata* Card. and Vard. X 750
Figure 397. Spores of *Pohlia flexuosa* (Mitt.) Broth. X 750
Figure 398. Spores of *Brachymenium exile* (Doz. and Molk.) Bryol. X 750
Figure 399. Spores of *Anomobryum subniditum* Card. and Vard. X 750
Figure 400. Spores of *Bryum argenteum* Linn, X 750
Figure 401. Spores of *Rhodobryum giganteum* (Hook.) Par. X 750
Figure 402. Spores of *Mnium coriaceum* Griff. X 750
Figure 403. Spores of *Hyophila involuta* (Hook.) Jage. X 750
Figure 404. Spores of *Ctenidium lychnites* (Mitt.) Broth. X 750
Figure 405. Spores of *Philonotis anisoclada* Card. and Vard. X 750
Figure 406. Spores of *Weisia macrospora* Card X 750
Figure 407. Spores of *Hypnodon perpusillus* (Thw. and Mitt.) C.M. X 750
Figure 408. Spores of *Schlotheimia grevilleana* Mitt, X 750
Figure 409. Spores of *Papillaria crocea* (Hamp.) Jaeg. X 750
Figure 410. Spores of *Rhegmatodon orthostegious* Mont X 750
Figure 411. Spores of *Thuidium tamariscellum* (C. M.) Bryol. Jav. X 750
Figure 412. Spores of *Rhynchostegium javanicum* (Bel.) Besch. X 750
Figure 413 Spores of *Sematophyllum subhumile* (C. M.) Fleisch. X 750
Figure 414 Spores of *Atrichum aculeatum* Card. and verd X 750
Figure 415 Spores of *Pogonatum microstomum* (R. Br.) Brid. X750
Figure 416 Spores of *Pogonatum neesii* (C. M.) Mitt. X 750

PLATE XXIV

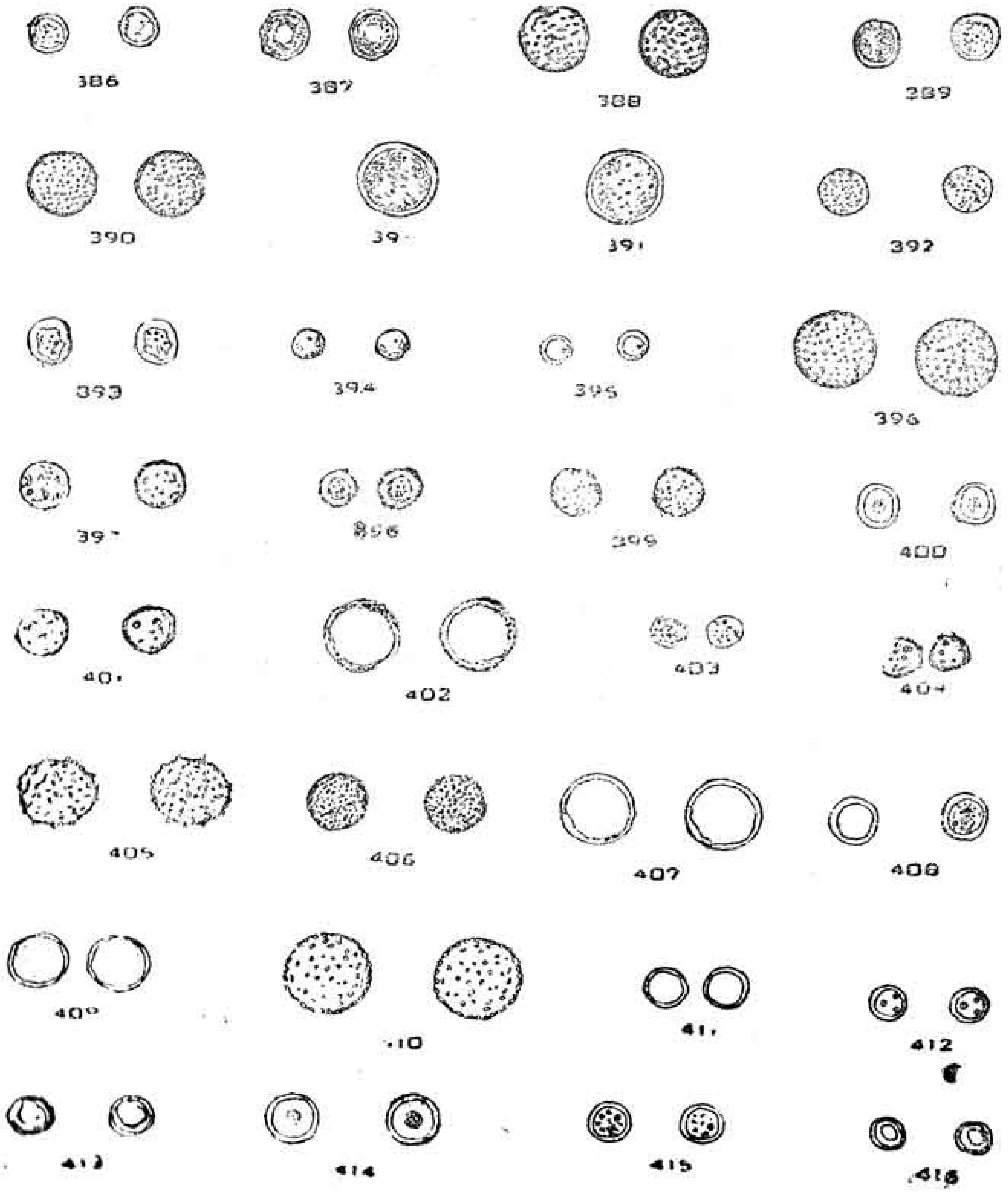


PLATE XXV

Figure 417. Vegetative bud of *Brothera leana* (Sull.) C. M. X 75

Figure 418. Multicellular hooked gemmae of *Brachymenium exile* (Doz. & Molk.) Bryol X 490

Figure 419. Vegetative bud on leaf of *Rhynchostegium javanicum* (Bel.) Fleisch. X 75

Figure 420. Stomata on apophysis of *Funaria hygrometrica* Hedw. X 285

Figure 421. Stomata on apophysis of *Pohlia flexuosa* (Mitt.) Broth. X 285

Figure 422. Foot of the sporophyte of *Hyophila involuta* (Hook) Jaeg. X 285

Figure 423. Foot of the sporophyte of *Tortula muralis* Hedw. X 285 (Perichaetial region stippled)

Figure 424. Foot of the sporophyte of *Bryum argenteum* Hedw. X 285

Figure 425. Foot of the sporophyte of *Barbula indica* (Schw.) Brid. X 285

Figure 426. Foot of the sporophyte of *Rhizogonium spiniforme* (Hedw.) Bruch. X 285

Figure 427. Foot of the sporophyte of *Rhynchostegium javanicum* (Bel.) Fleisch. X 285

Figure 428. Foot of the sporophyte of *Atrichum aculeatum* Card. & Varde X 285

Figure 429. Foot of the sporophyte of *Pogonatum microstomum* (R.Br.) Brid. X 285

PLATE XXV

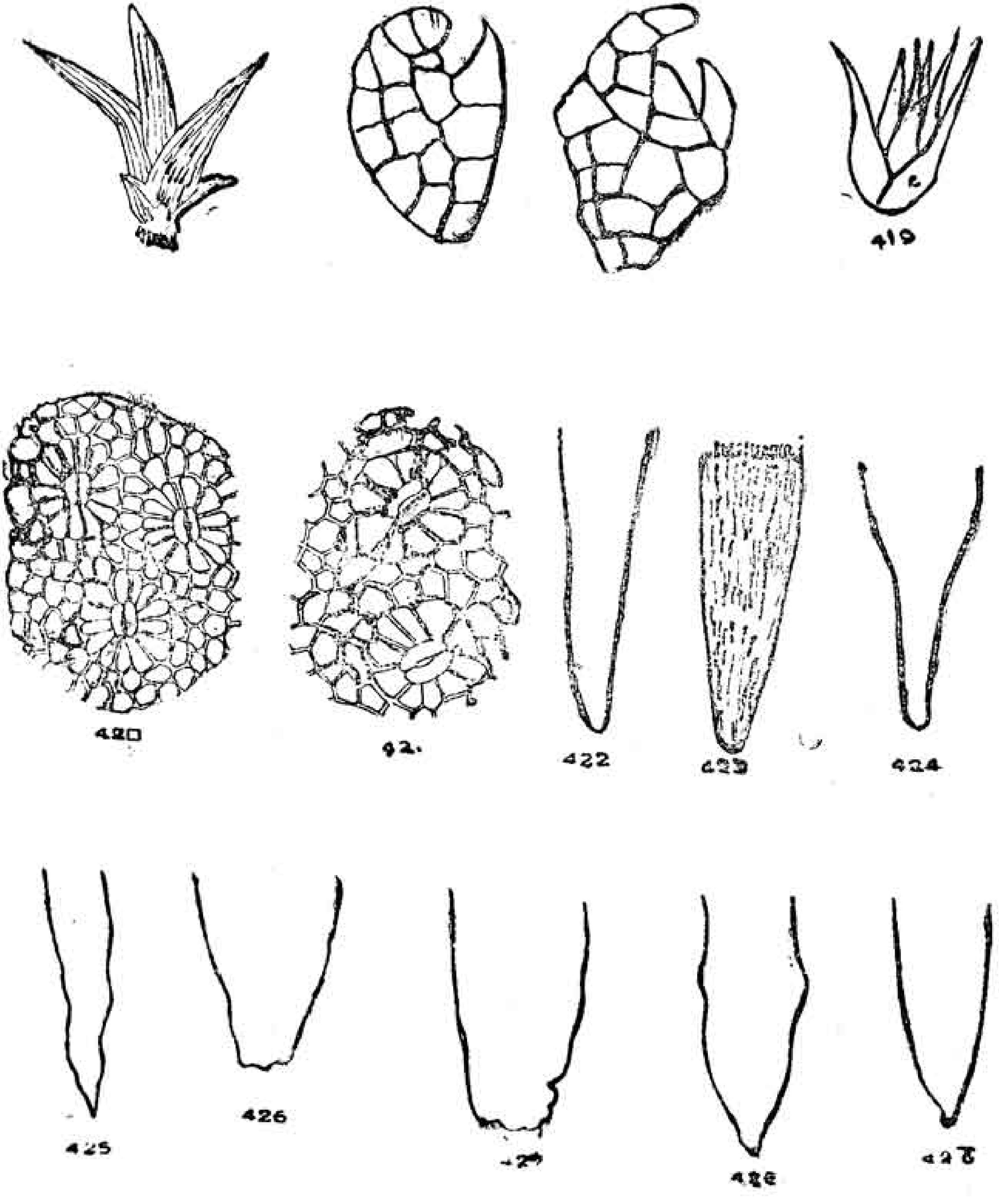


PLATE-XXVI

Figure 430. Transverse section of axis of *Hookeria acutifolia* Hook. X 75.

Figure 431. Transverse section of axis of *Hookeria acutifolia* Hook. Sector passing through centre of axis X 285.

Figure 432. Transverse section of axis of *Leucobryum neilgherrense* C. M. X 285.

Figure 433. Transverse section of axis of *Hypopterygium tenellum* X 750.

Figure 434. Transverse section of axis *Distichophyllum succulentum* (Mitt.) Broth. X 285.

Figure 435. Transverse section of axis of *Distichophyllum succulentum* (Mitt.) Broth. Centre of axis enlarged. X 750.

Figure 436. Transverse section of axis of *Floribundaria floribunda* (Doz. & Molk) Fleisch. X 285.

Figure 437. Transverse section of axis of *Aerobryopsis longissima* (Doz. & Molk.) Fleisch. Half of section X 285.

Figure 438. Transverse section of axis of *Warburgiella leptorhynchoides* (Mont) Fleisch. X 285.

Figure 439. Transverse section of axis of *Sematophyllum subhumile* (C. M.) Fleisch. X 285

PLATE XXVI

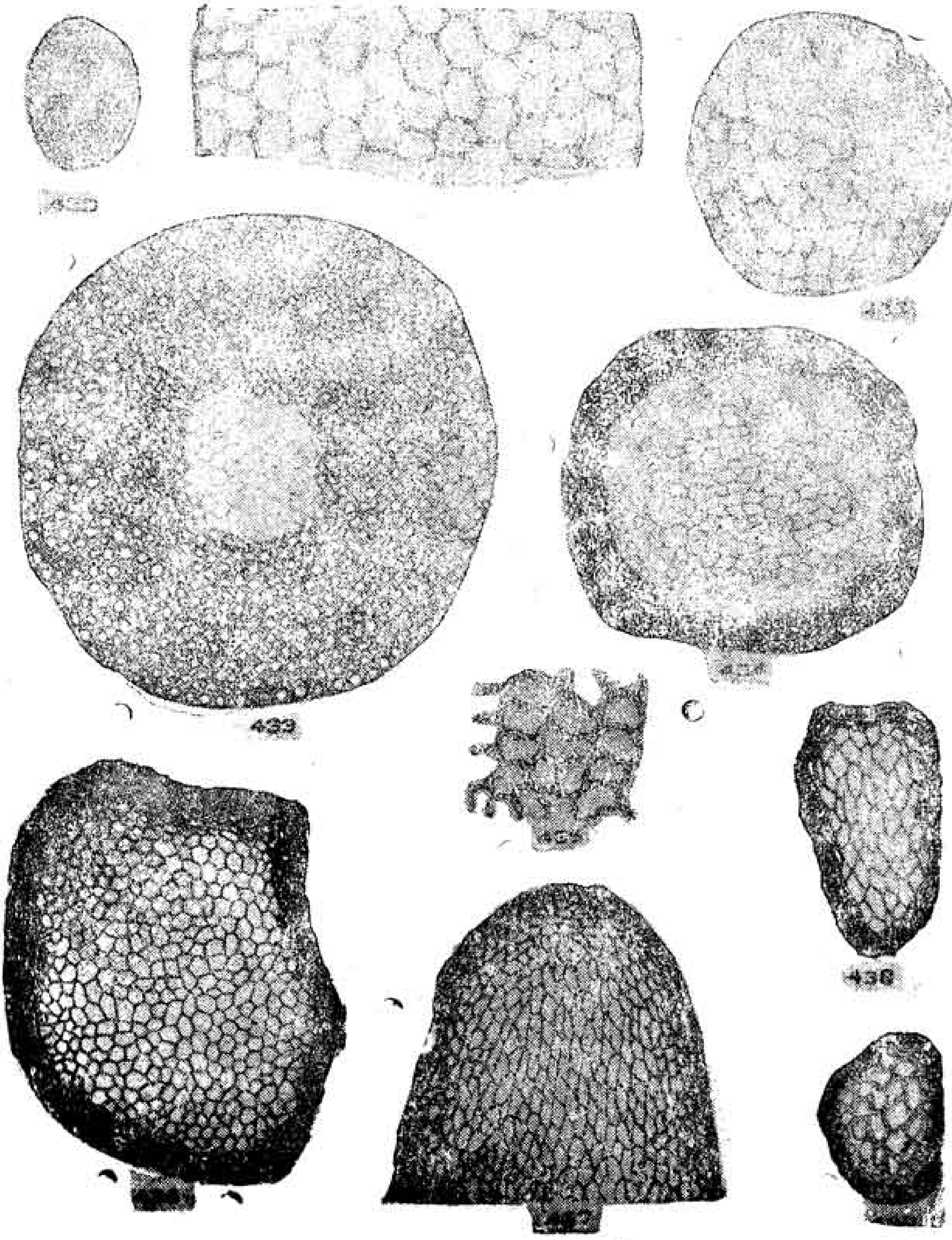


PLATE XXVII

Figure 440. Transverse section of axis of *Leucobryum scalare* C. M. X 285.

Figure 441. Transverse section of axis of *Schlotheimia grevilleana* Mitt. X 285.

Figure 442. Transverse section of axis of *Bartramia madurensis* Dix. & Vard. X 490.

Figure 443. Transverse section of axis of *Myurium warburgii* (C. Mull.) Fleisch. X 285.

Figure 444. Transverse section of axis of *Papillaria crocea* (Hamp.) Jaeg X 285.

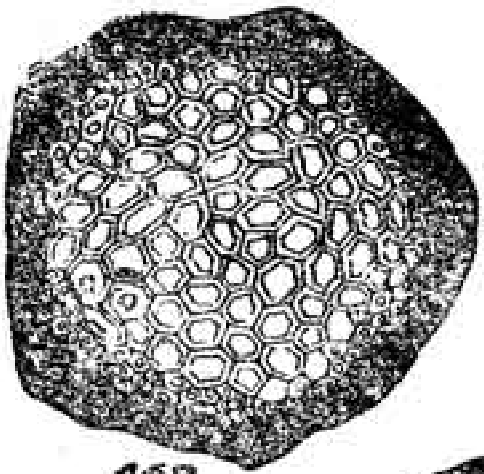
Figure 445. Transverse section of axis of *Barbella pendula* (Sull) Fleisch. X 285.

Figure 446. Transverse section of axis of *Homaliodendron flabellatum* (Dix. Sm.) Fleisch. X 75.

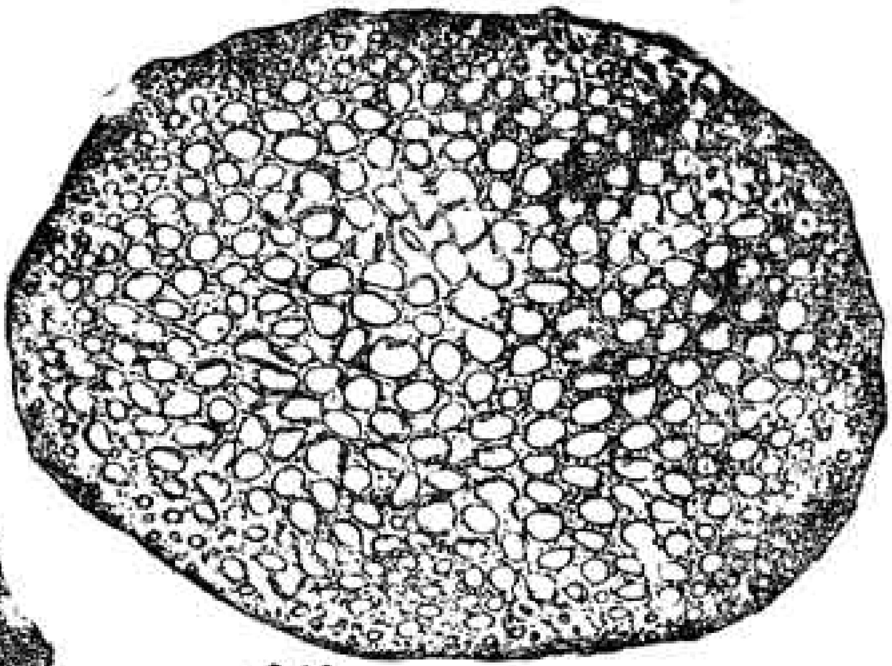
Figure 447. Transverse section of axis of *Homaliodendron flabellatum* (Dix. Sm.) Fleisch. (Sector- X 285.

Figure 448. Transverse section of axis of *Foreauella indica* Dix. & Vard. X 285.

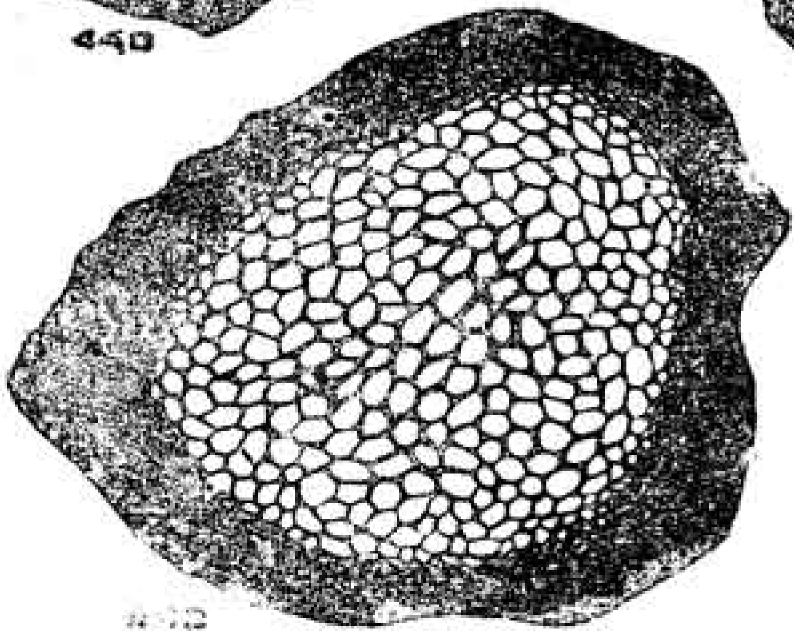
PLATE XXVII



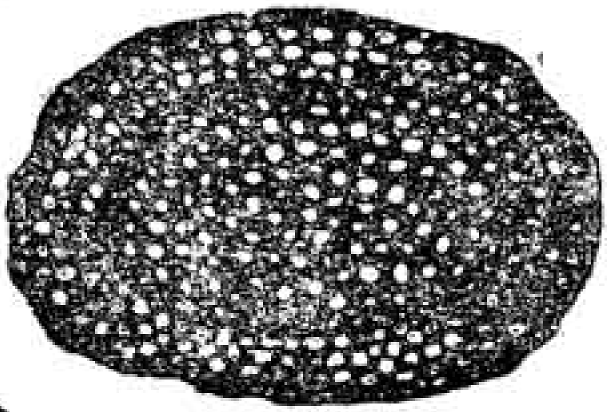
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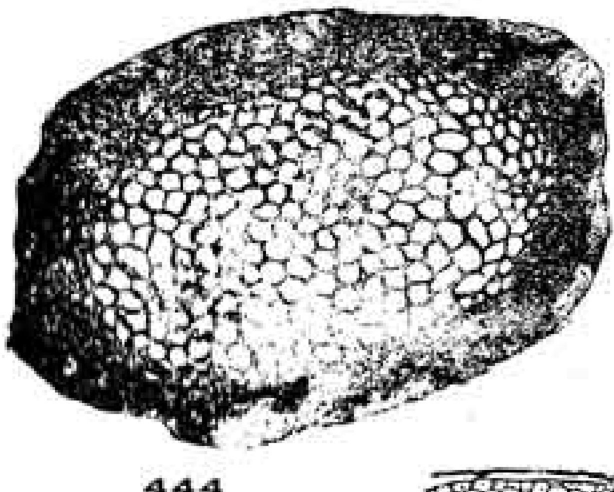
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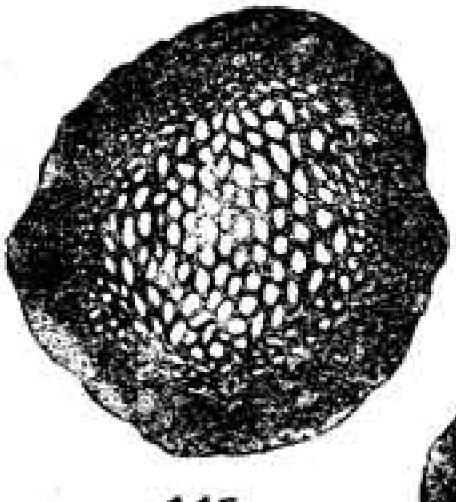
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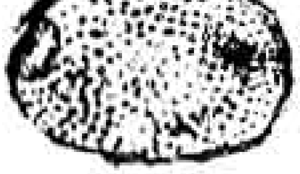
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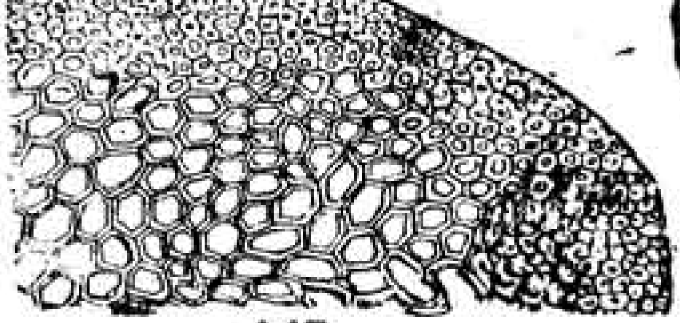
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PLATE XXVIII

Figure 449. Transverse section of axis of *Philonotis anisoclada* Card. & Vard. X 75.

Figure 450. Transverse section of axis of ·*Philonotis anisoclada* Card. & Vard. Centre enlarged X 750.

Figure 451. Transverse section of axis *Trachypus bicolor* Rein. & Hornsch. X 285.

Figure 452. Transverse section of axis *Trachypus bicolor* Rein. & Hornsch. Centre enlarged X 750.

Figure 453. Transverse section of axis of *Erythrodontium julaceum* (Hook.) Par. X 285.

Figure 454. Transverse section of axis of *Erythrodontium julaceum* (Hook.) Par. Centre enlarged X 750.

Figure 455. Transverse section of axis of *Ctenidium lychnites* (Mitt.) Broth. X 285.

Figure 456. Transverse section of axis of *Hypnum cupressiforme* Hedw. X 285.

Figure 457. Transverse section of young axis of *Mnium coriaceum* Griff. X 285

Figure 458. Transverse section of axis of *Fissidens schimidii* X 285.

Figure 459. Transverse section of axis of *Ditrichum amoenum* (Thw. & Mitt.) Par. 285

PLATE XXVIII

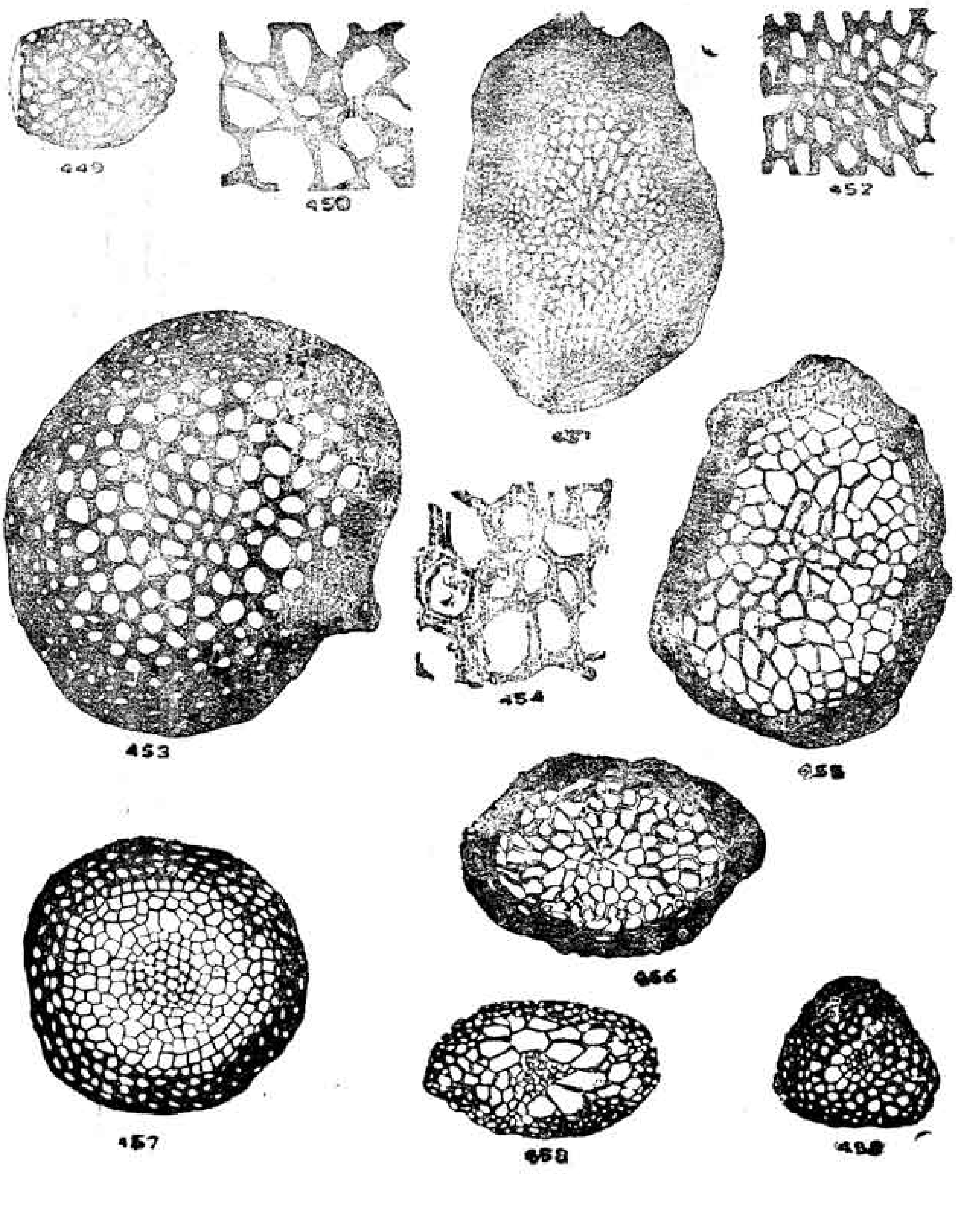


PLATE-XXIX

Figure 460. · Transverse section of axis of *Meteoriopsis reclinata* (C. M.) Fleisch. X 285

Figure 461. Trarsverse section of axis of *Meteoriopsis squarrosa* (Hook.) Fleisch. sector passing through centre of axis X 285

Figure 462. Transverse section of axis of *Rhynchostegium javanicum* (Bel.) Fleisch. X 285

Figure 463. Transverse section of axis o9 *Campylopus nodiflorus* (C. M.) Jaeg. X 285

Figure 464. Transverse section of axis of *Thysanomitrium depallieri* Card. X 285

Figure 465. Transverse section of axis of *Hyophila validinervis* Card & Vard. X 285

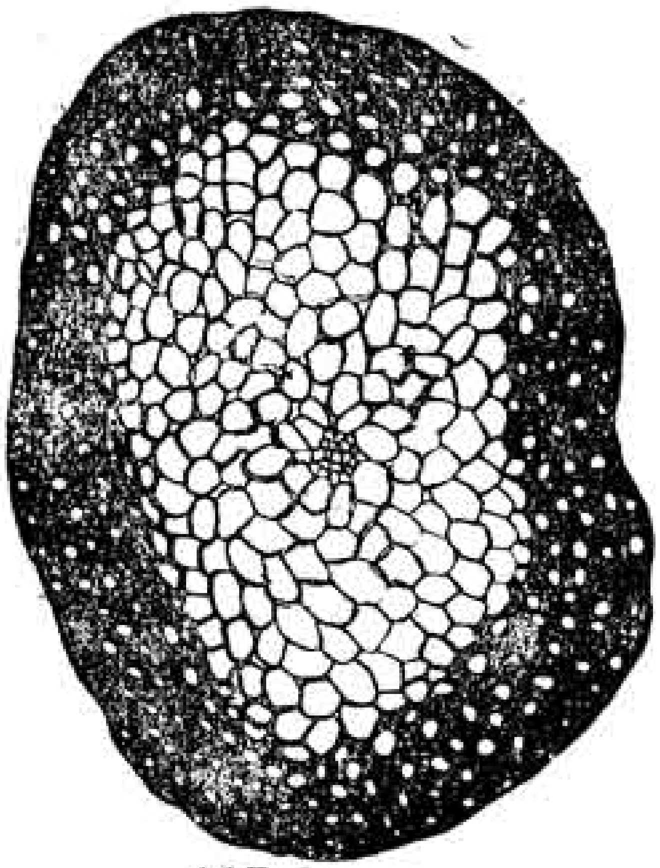
Figure 466. Transverse section of axis *Funaria submarginata* X 285

Figure 467. Transverse section of axis of *Rhodobryum giganteum* (Hook.) par. X 75

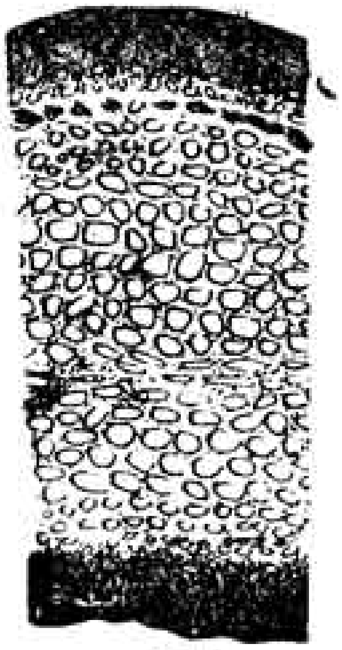
Figure 468. Transverse section of axis of *Barbella tenax* (C. M.) Broth. X 285

Figure 469. Transverse section of axis of *Fleuropus nilghiriense* (Mont.) Toyama X 285

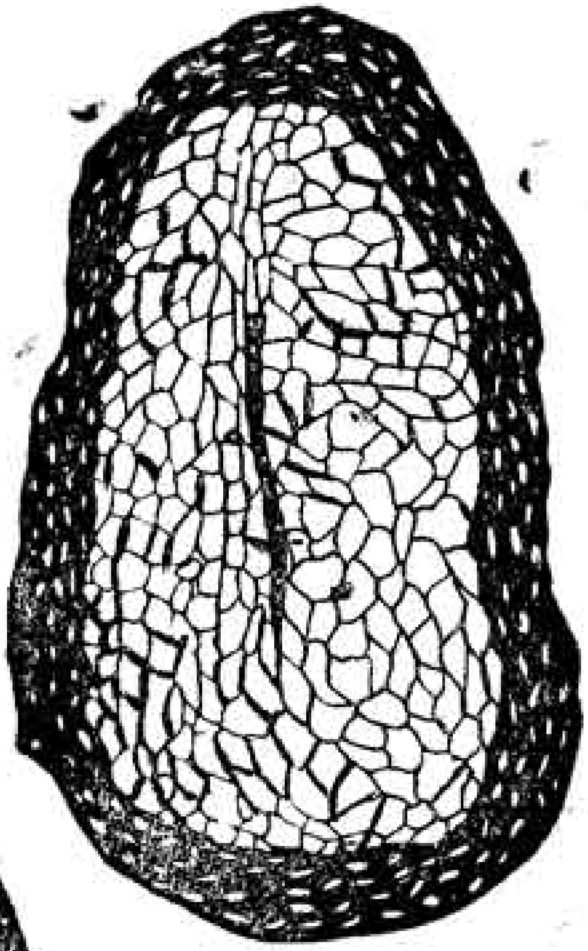
PLATE XXIX



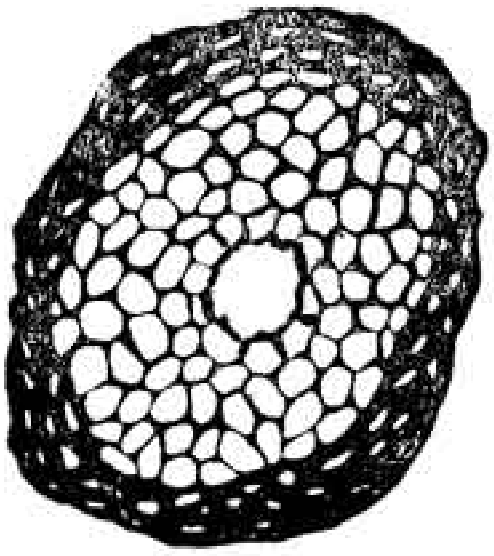
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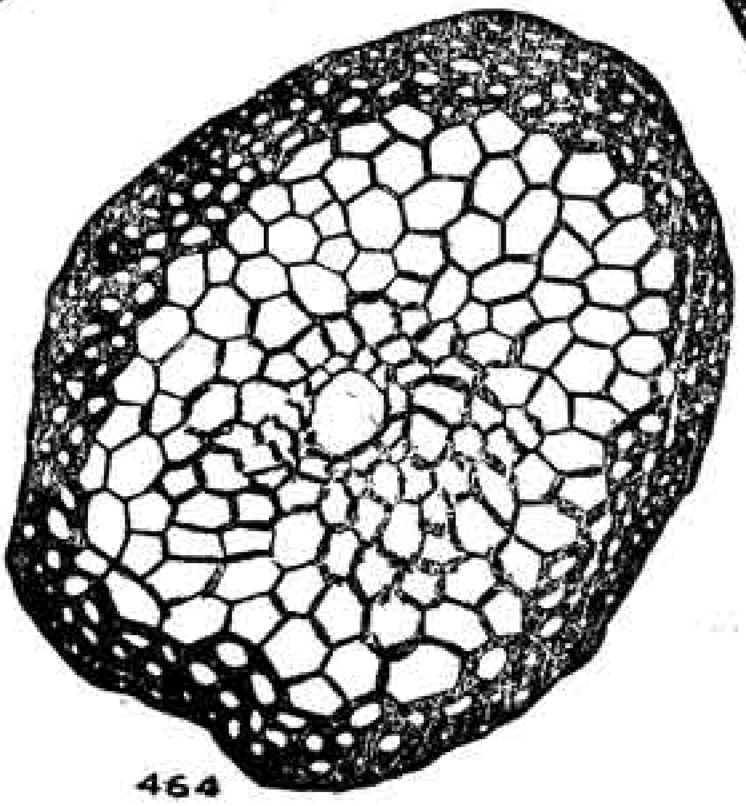
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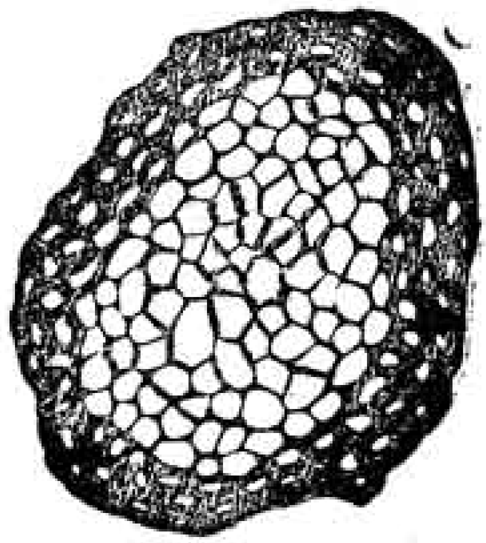
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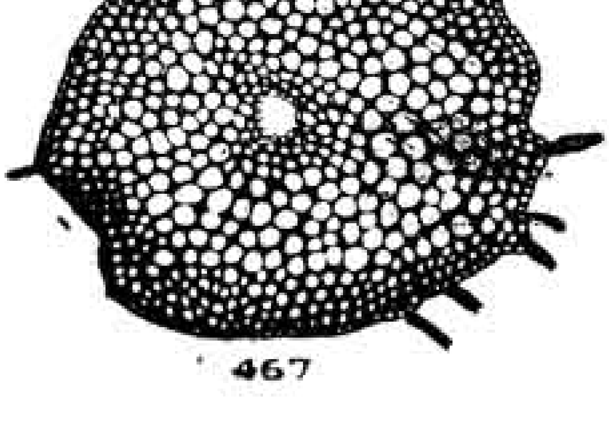
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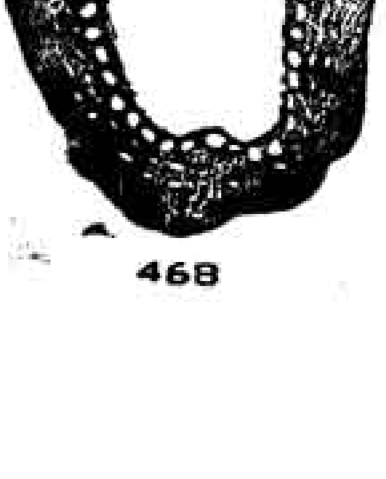
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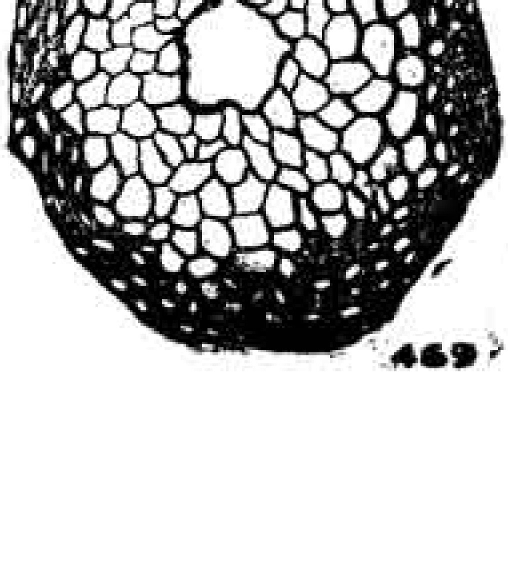
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PLATE-XXX

Figure 470. Transverse section of old axis of *Mnium coriaceum* Griff. Centre enlarged. X 750

Figure 471. Transverse section of axis of *Rhegmatodon orthostegius* Mont. X 285

Figure 472. Transverse section of axis of *Pterobryopsis orientalis* (C. M.) Fleisch. Sector passing through centre of axis. X 750

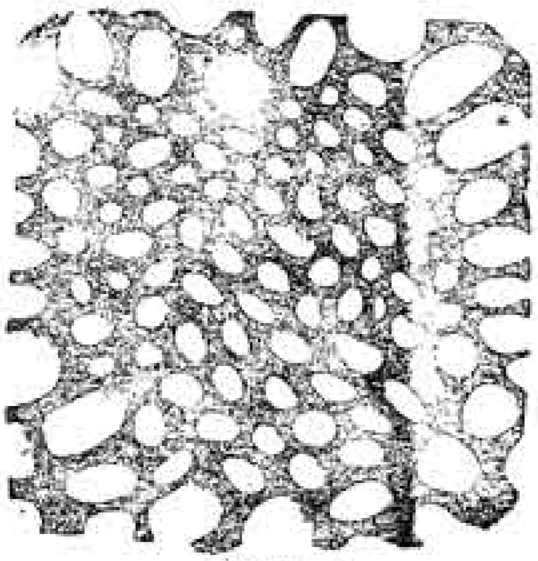
Figure 473. Transverse sction of young axis of *Atrichum aculeatum* Card. & Vard. Centre of axis enlarged X 750

Figure 474. Transverse sction of old axis of *Atrichum aculeatum* Card. & Vard. X 285

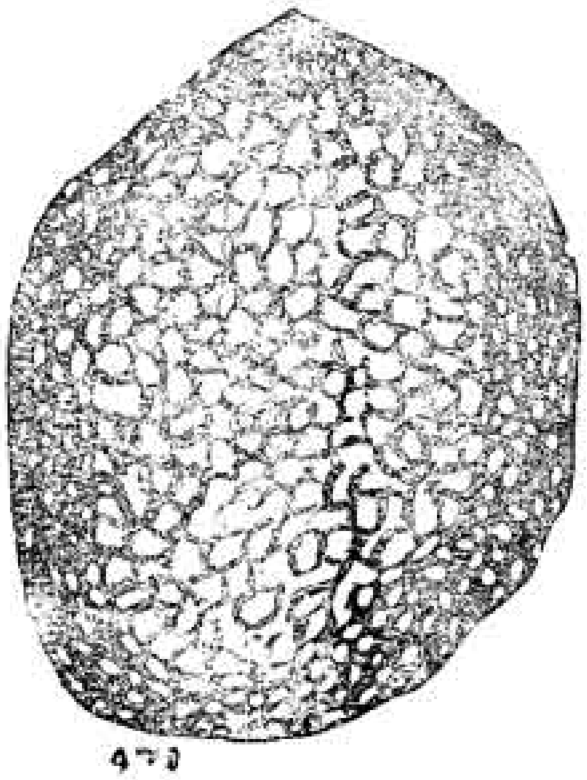
Figure 475. Transverse section of old axis of *Pogonatum neesii* (C. M.) Mitt. X 285

Figure 476. Transverse section of seta (at its base) of *Pogonatum neesii* (C. M.) Mitt. X 285

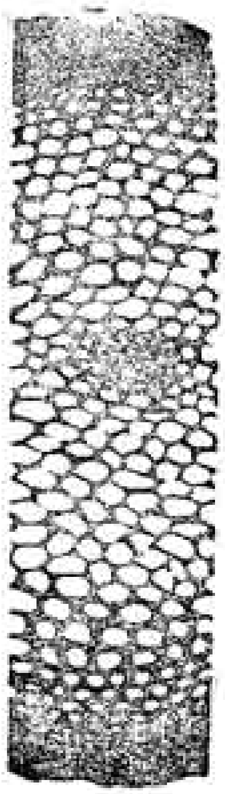
PLATE XXX



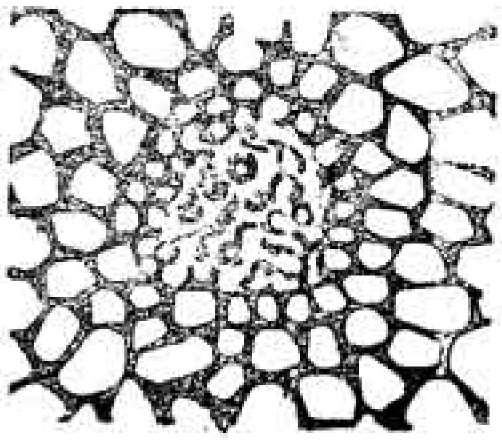
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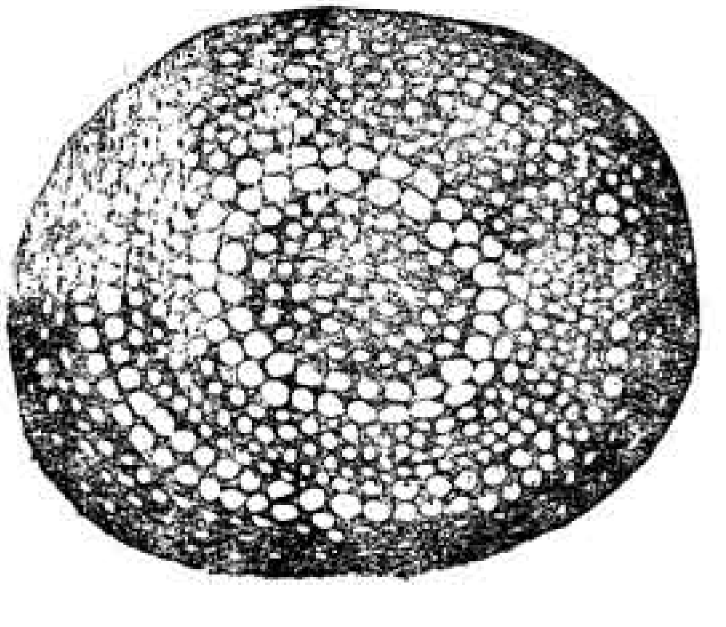
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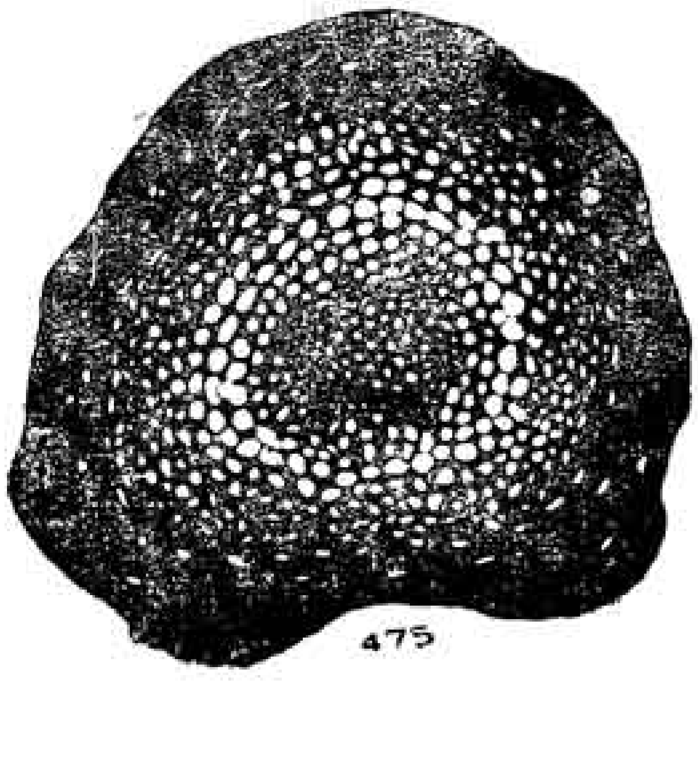
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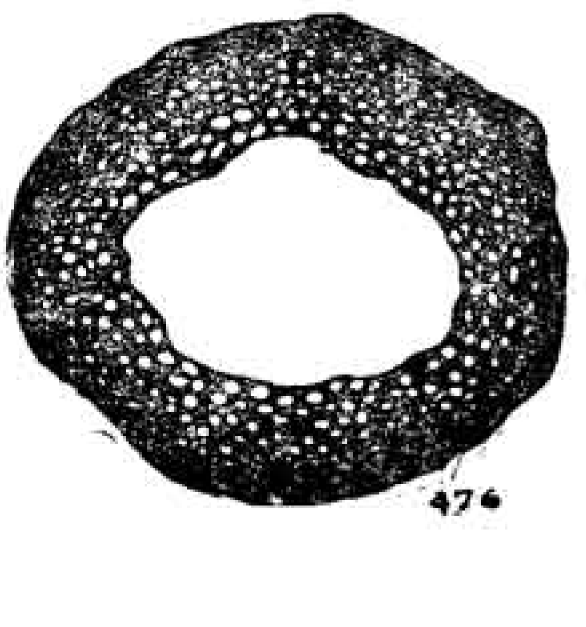
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PLATE - XXXI

(Photographs of the Herbarium)

Figure 477. *Fissidens schimidii* C. M. plants X 2

Figure 478. Plants of *Ditrichum amoenum* (Thw. & Mitt.) par. X 3

Figure 479. Plants of *Trematodon ceylonensis* C. M. X 1

Figure 480. Plants of *Campylopus nodiflours* (C. M.) Jaeg. X 1

Figure 481. Plants of *Tnysanomitrium depalieri* Card. X 3 4

Figure 482. Plants of *Thysanomitrium lioneurum* (Ther. & Vard.) Broth. X 1–1/4

Figure 483. Plants of *Brothera leana* (Sul.) C. M. X 1-1/2

Figure 484. Plants of *Dicranodontium fragile* (Hook.) Broth. X 1-1/4

Figure 485. Plants of *Leucobryum neilgherrense* C. M. X 2

Figure 486. Ptants of *Leucobryum scalare* C. M. X 1.5

Figure 487. Plants of *Tortula muralis* Hedw. X 4

Figure 488. Plants of *Barbula indica* (Schw.) Brid X 2

Figure 489. Plants of *Trichostomum cylindricum* (Bruch.) C. M. X 1.5

Figure 490. Pants of *Weisia macrospora* Card. X 1

Figure 491. Pants of *Hyophila involuta* (Hook.) Jage X 2

PLATE XXXI

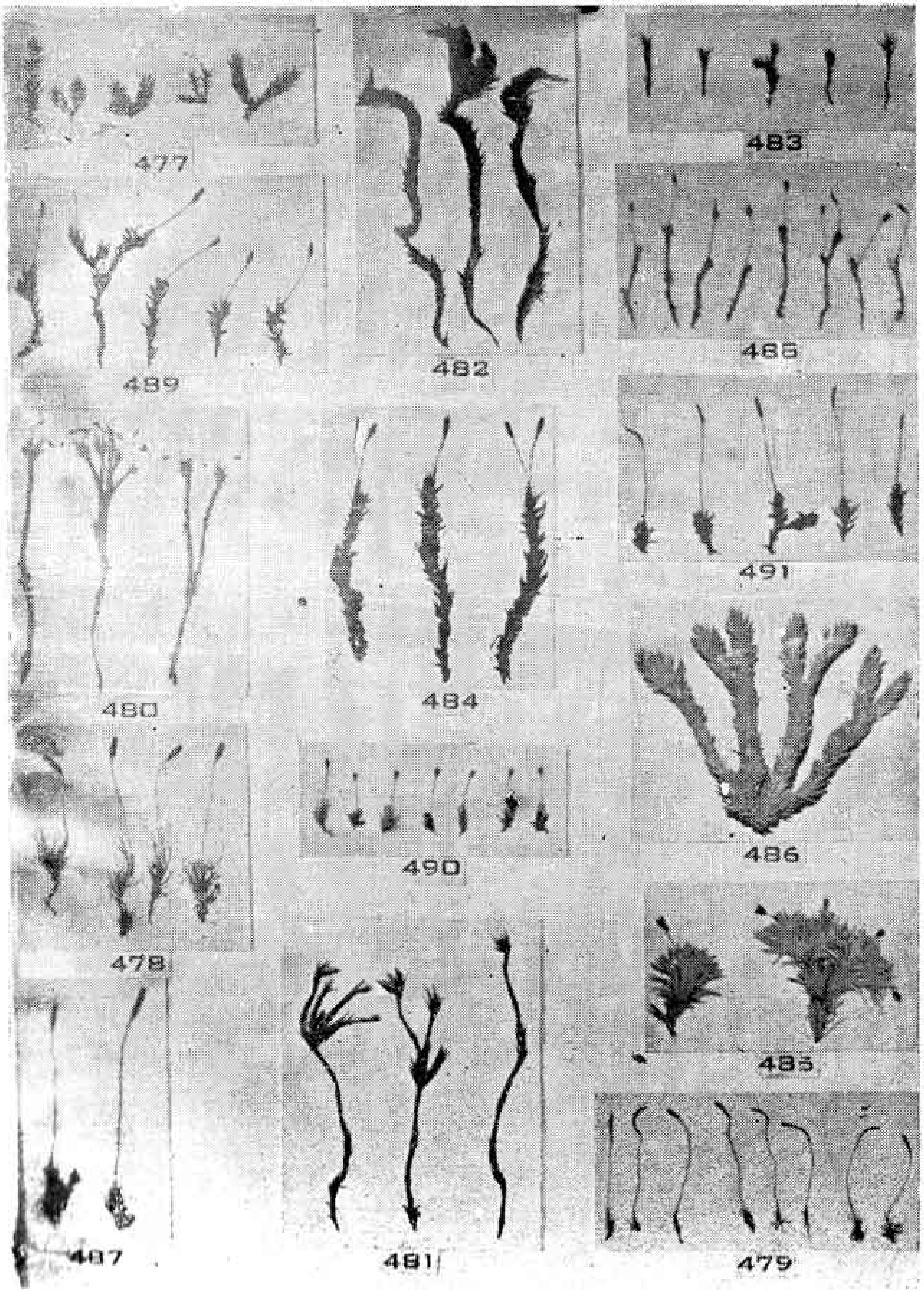


PLATE XXXII

(Photographs of the Herbarium)

Figure 492. Plants of *Hyophyla validinervis* Card. & Vard. X 2-1/2

Figure 493. Plants of *Rhacomitrium javanicum* Bryol. X 1

Figure 494. Plants of *Funaria hygrometrica* Hew. X 1

Figure 495 Plants of *Funaria submarginata* Carp. & Vard. X 2-1/2

Figure 496. Plants of *Pholia flexuosa* (Mitt.) Broath. X 3

Figure 497. Plants of *Brachymenium leptostomoides* (C. M) Schimp. X 1-1/2

Figure 498. Plants of *Anomobryum subniditum* Card. & Vard. X 1-1/2

Figure 499. Plants of *Bryum argenteum* Linn. X 1

Figure 500. Plants of *Rhodobryum giganteum* (Hook.) Par. X 1

Figure 501. Branch of *Mnium coriaceum* Griff. 1

Figure 502. Plants of *Rhizogonium spiniforme* (Hedw.) Bruch. X 1-1/2

Figure 503. Plants of *Bartramia madurensis* Dix. & Vard. X 1-1/2

Figure 504. Plants of *Philonotis anisoclada* Card. & Vard. X 1-1/4

Fignre 505. Plants of *Hypnodon perpusillus* Thw. & Mitt. X 1-3/4

PLATE XXXII

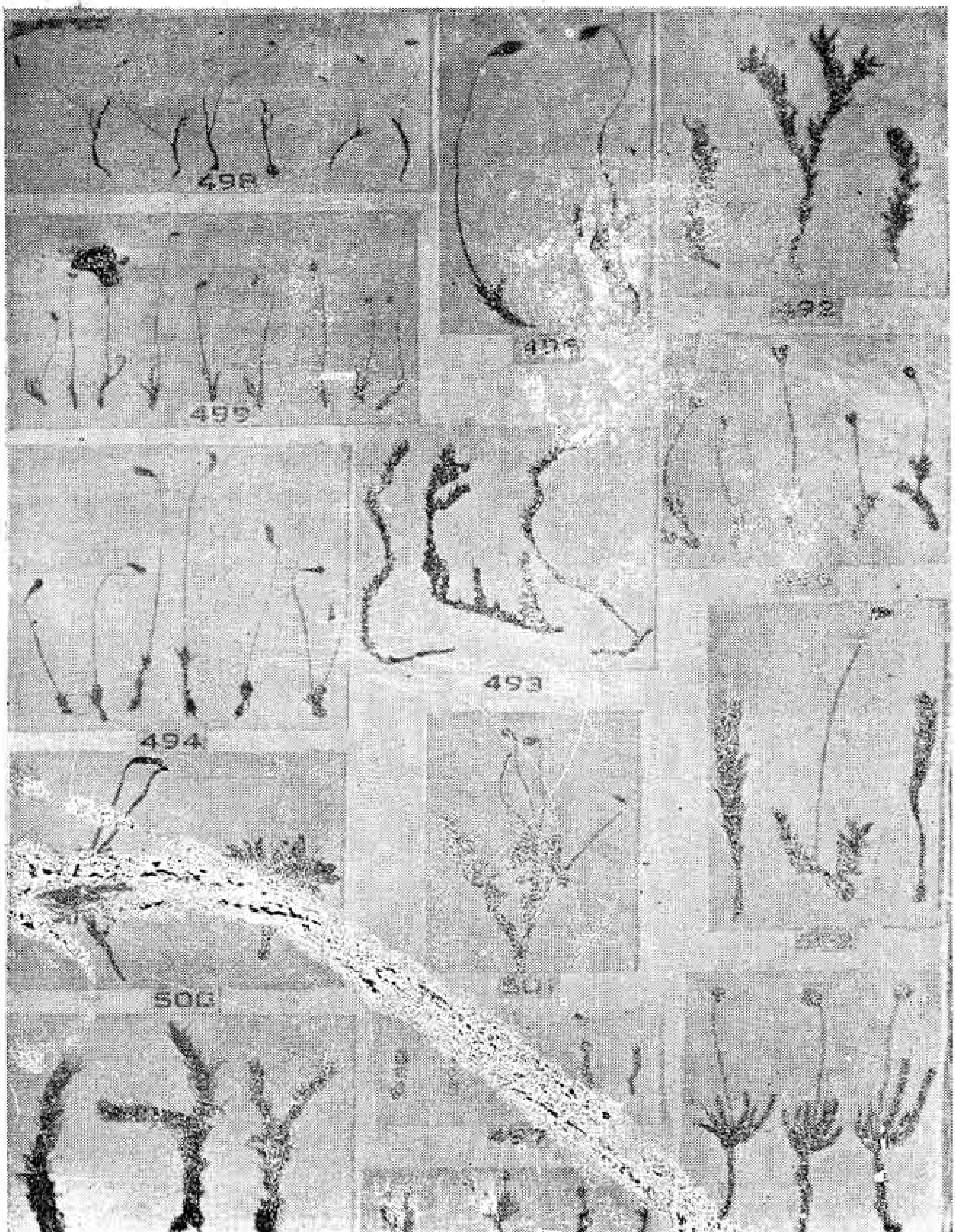


PLATE - XXXIII

Figure 506. Branches of *Schlotheimia grevilleana* Mitt. X 2-1/4

Figure 507. Branch of *Trachypus bicolor* Rein. & Hornsch. X 1-3/4

Figure 508. Branch of *Trachypus humilis* Lindb. var. *humilis* Zanten. X 2

Figure 509. Branch of *Trachypodopsis serrulata* (Beauv.) Fleisch. var. *crispatula* Hook. Zanten. X 1

Figure 510. Branch of *Myurium warburgii* (C. M.) Felisch. X 1-1/2

Figure 511. Branch of *Petrobryopsis orientlis* (C. M.) Fleisch. X 1

Figure 512. Branch of *Papillaria crocea* (Hamp.) Jaeg. X 3/4

Figure 513. Branch of *Aarobryopsis longissima* Diz. & Molk.) Fleisch. X 1

Figure 514. Plant of *Barbella tenax* (C. M.) Broth. X 1

Figurd 515 Branch of *Barbella determessi* (Rein. & Card.) Fleisch. X 3/4

Figure 516. Branch of *Barbella pendula* (Sull.) Fleisch. X 7/8

PLATE XXXIII

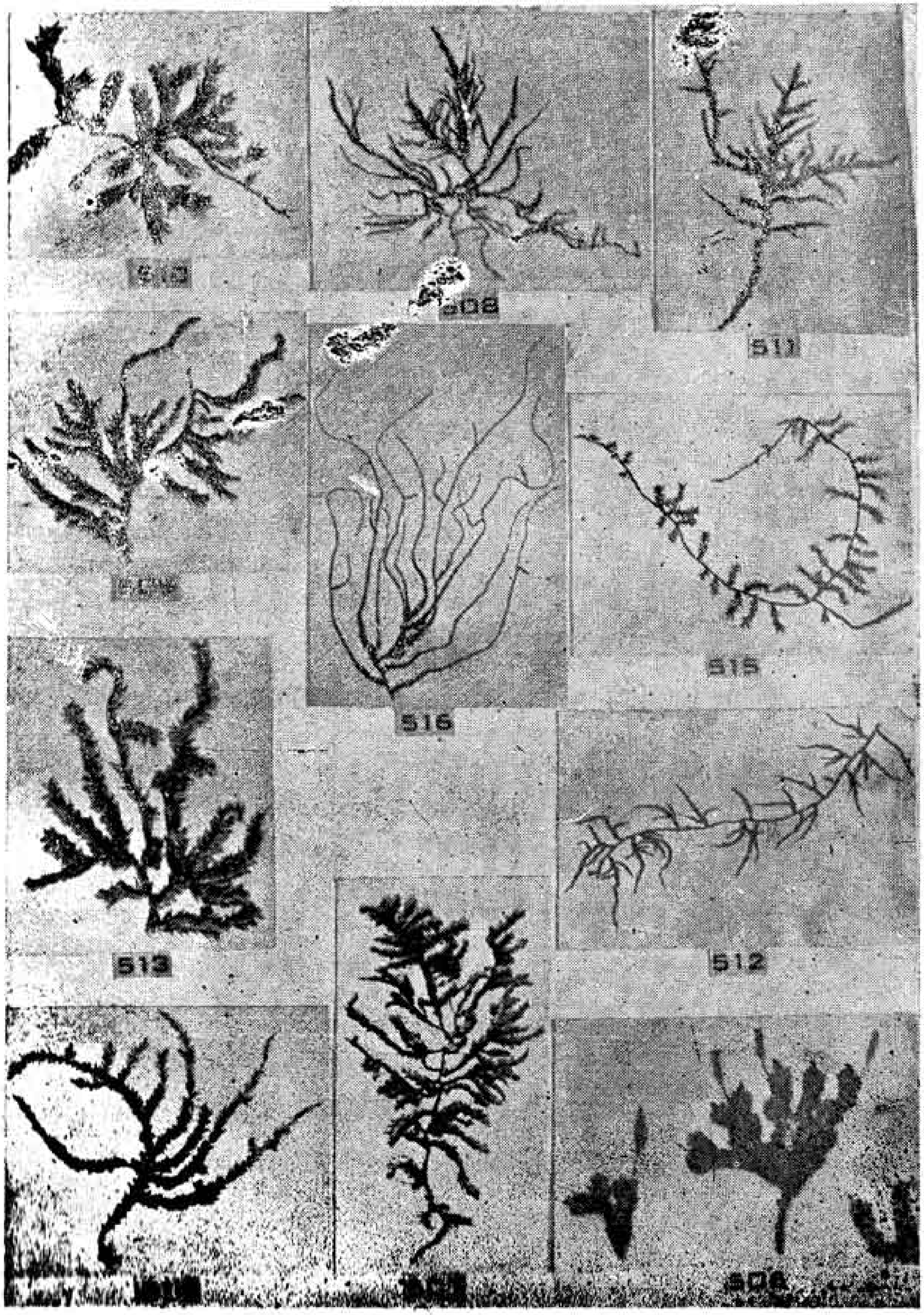


PLATE - XXXIV

(Photographs of the Herbarium)

Figure 517. Branch of *Floribundaria floribunda* (Doz. & Molk.) Fleisch. X 1

Figure 518. Branch of *Meteoriopsis squarrosa* (Hook.) Fleisch. X 1

Figure 519i Branch of *Meteoriopsis reclinata* (C. M) Fleisch. X 1

Figure 520. Plants of *Homaliodendron exiguum* (Bryol) & Jav.) Fleisch. X 1-1/4

Figure 521. Plant of *Homaliodendron flabellatum* (Dix. Sm.) Fleisch. X 1

Figure 522. Pants of *Distichophyllum succulentum* (Mitt.) Broth. X 1-1/2

Figure 523. Plants *Hookeria acutifolia* Hook. X 2

Figure 524. Branch of *Hypopterygium tenellum* Lac. X 2

Figure 525. Branch of *Rhegmatodon orthostegius* Mont.

Figure 526. Plants of *Herpetineurm toccoae* (Sull. & Lesq.) X 1

Figure 527. Plant of *Rhynchostegium javanicum* (Bel.) Besh. X 1

PLATE XXXIV

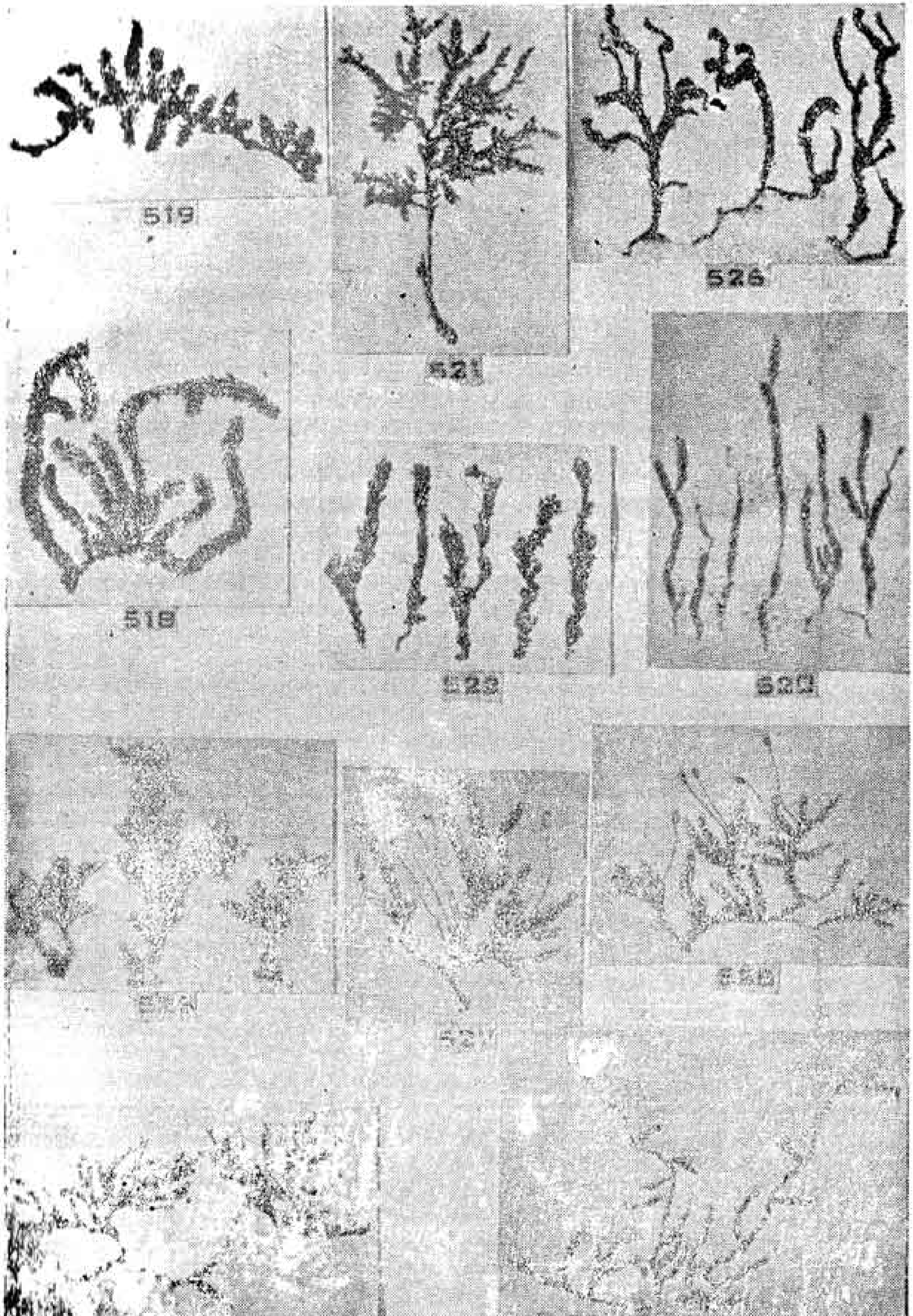


PLATE - XXXV

(Photographs of the Herbarium)

Figure 527 - 1 Plants of *Thuidium tamariscellum* (C.M.) Bryol. Jav. X 2

Figure 528. Branches of *Erythrodontium julaceum* (Hook.)Pae. X 1-1/2

Figure 528 - 1 Plant of *Pleuropus nilghiriense* (Mont.) Toyama X 1

Figure 529. Branch of *Foreauella indica* Dix. & Vard. X 1-1/2

Figure 530. Branch of *Sematophyllum subhumile* (C. M.) Fleisch. X 2

Figure 531. Branch of *Warburgiella leptorrhynchoides* (Mont.) Fleisch. X 2

Figure 532. Plant of *Hypnum cupressiforme* Hedw. X 1

Figure 533. Plant of *Taxiphyllum taxirameum* (Mitt.) Fleisch. X 1

Figure 534. Branch of *Ctenidium lychnites* (Mitt.) Broth. X 2-1/4

Figure 535. Plants of *Atrichum aculeatum* Card. & Vard. X 2

Figure 536. Plants of *Pogonatum microstomum* (R. Br.) Brid. X 2/3

Figure 537. Plants of *Pogonatum neesii* (C. M.) Mitt. X 1-1/4

PLATE XXXV

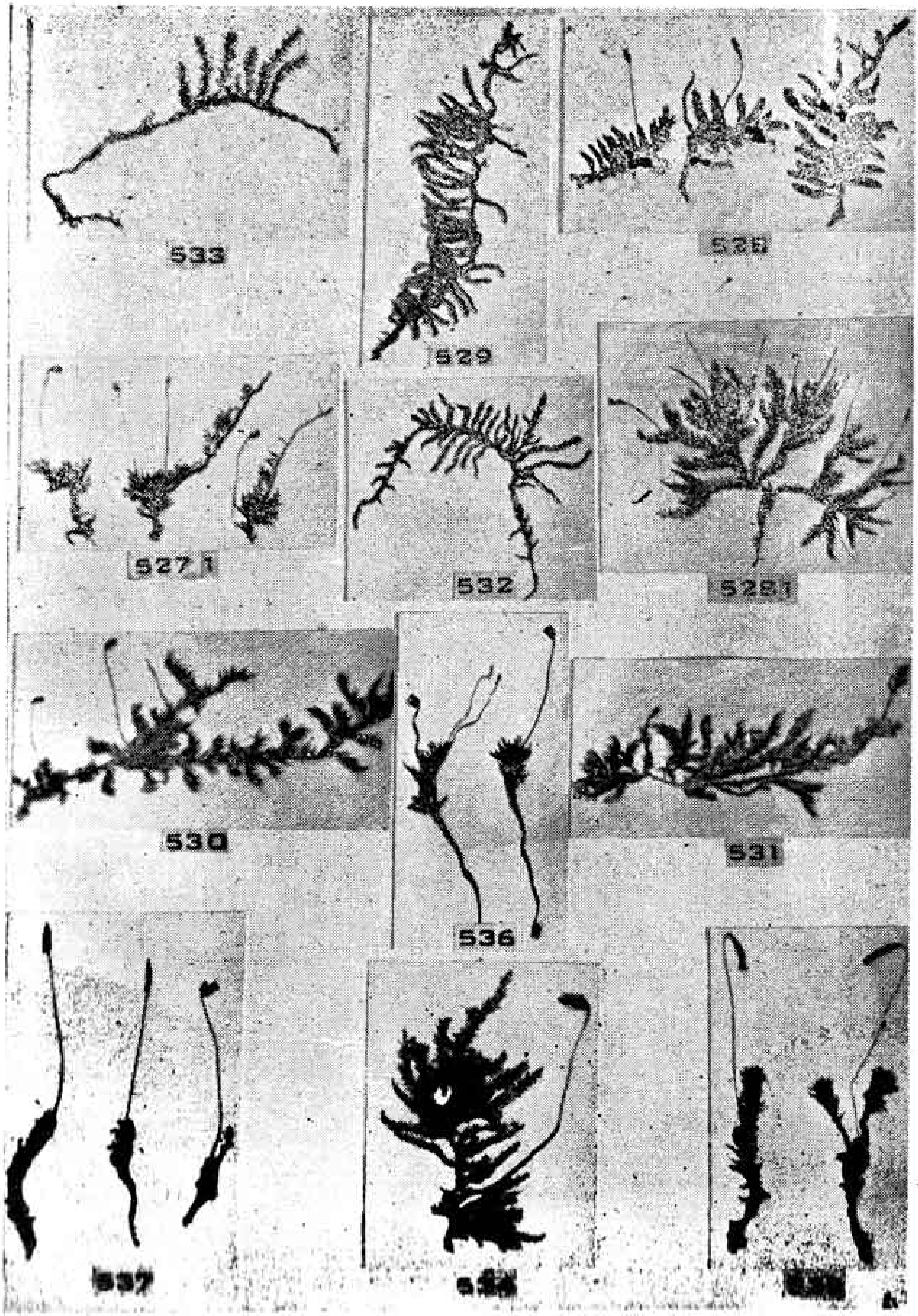


PLATE - XXXVI

(Photographs of the mosses in nature)

Figure 538. Plants of *Fissidens schimidii* C. M. in natural habitat at Trivandrum on loose soil. X 1/5

Figure 539. plants of *Campylopus nodiflorus* (C. M.) Jaeg. in small tufts at Ootacamund. X 1/4

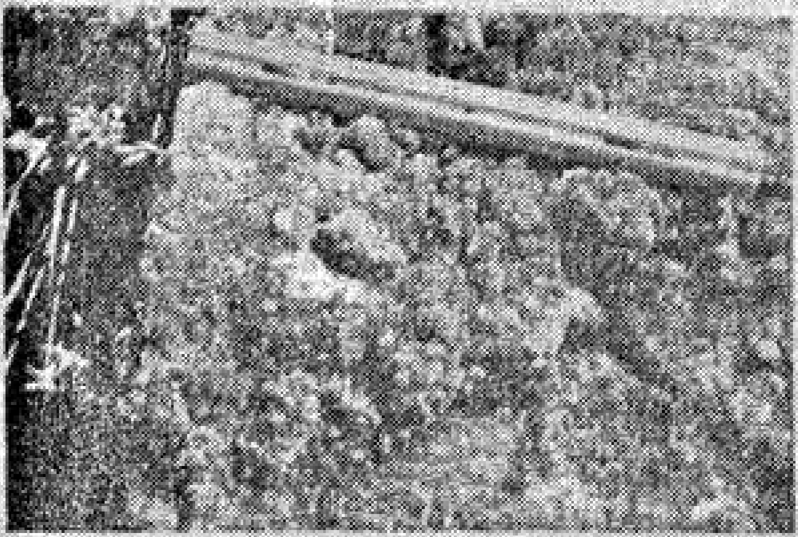
Figure 540. Plants of *Rhodobryum giganteum* (Hook.) Par. Flash photograph in natural habitat at Kodaikanal. X 1/6

Figure 541. Plant carpet of *Schlotheimia grevilleana* Mitt. on rock at Kodaikanal. X 1/5

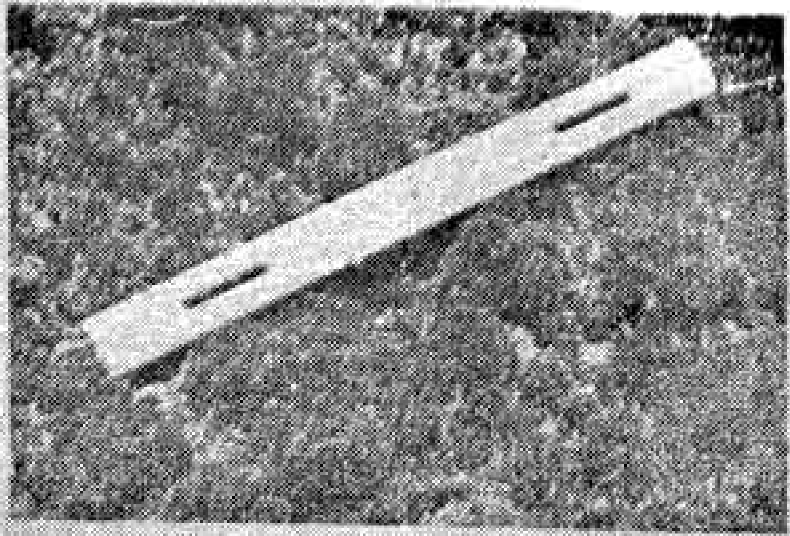
Figure 542. Plants of *Meteorioposis reclinata* (C. M) Fleisch. at Kodaikanal. X 1/5

Figure 543. Pants of *Trachypus bicolor* Rein & Card. on rock at Kodaikanal. X 5

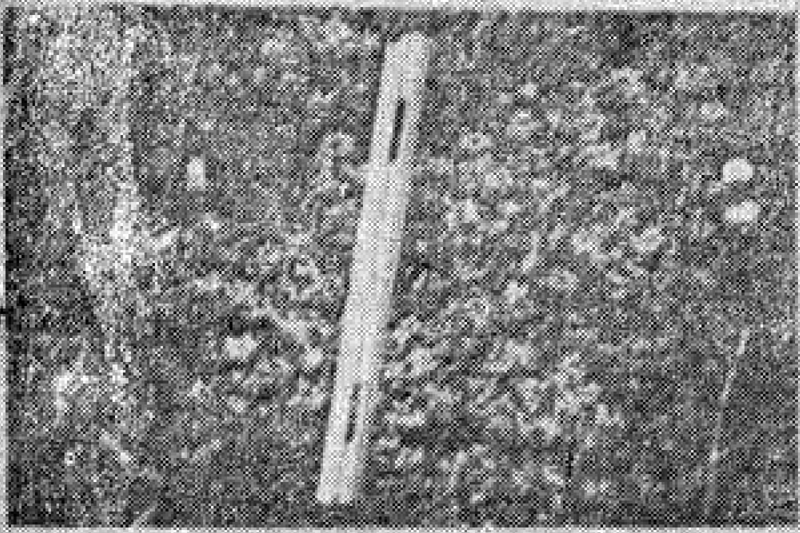
PLATE XXXVI



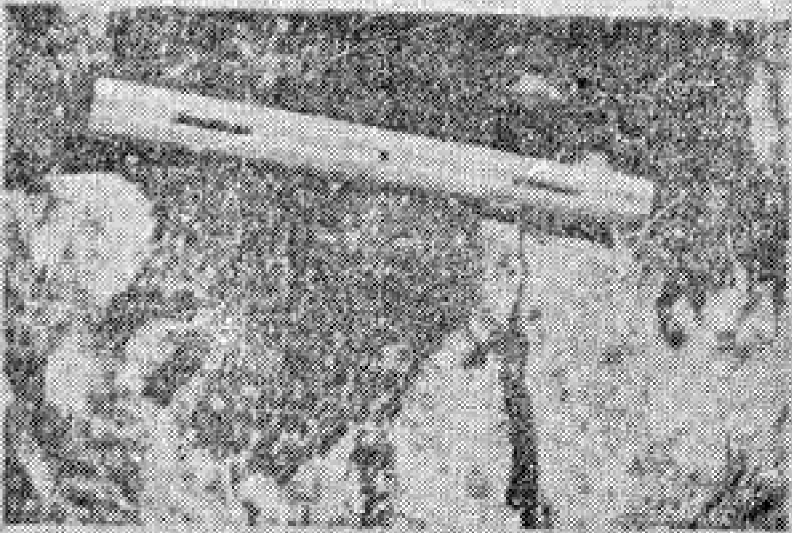
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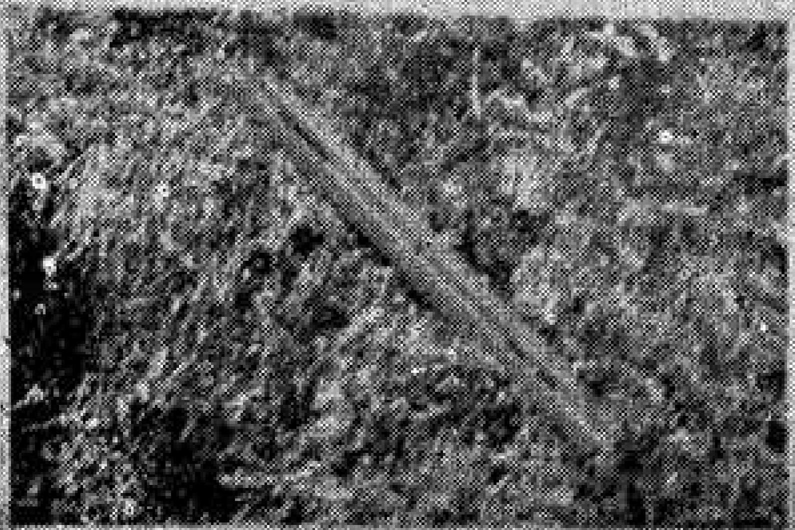
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PLATE - XXXVII

(Photographs of the mosses in nature)

Figure 514. Plants of *Thuidium tamariscellum* (C. M.) Bryol Jav. at Kodaikanal. X 1/5

Figure 545. Plants of *Floribundaria floribunda* (Doz. & Molk.) Fleisch. at Kodaikanal. X 1/5

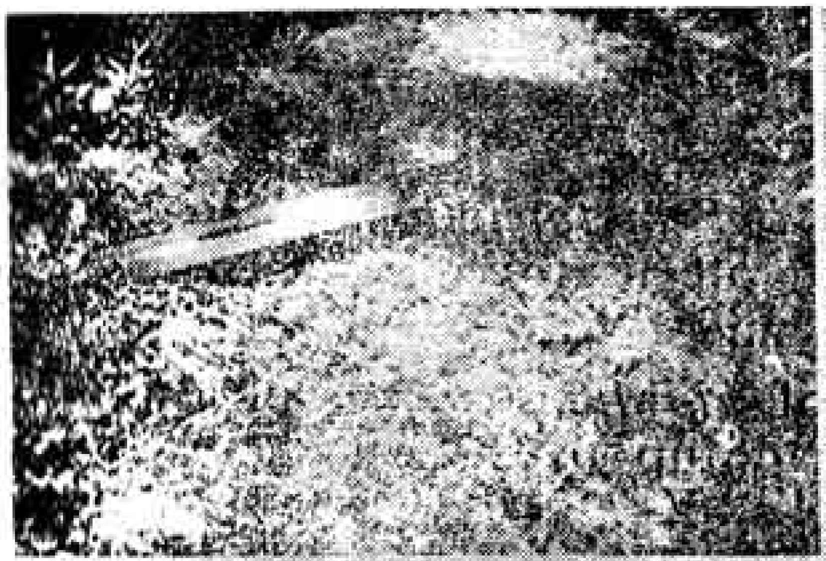
Figure 546. Plants of *Rhegmatodon orthostegius* Mont. at Kodaikanal. X 1/8

Figure 547. Plants of *Barbella determessi* (Rein. & Card.) Fleisch. X 1/7

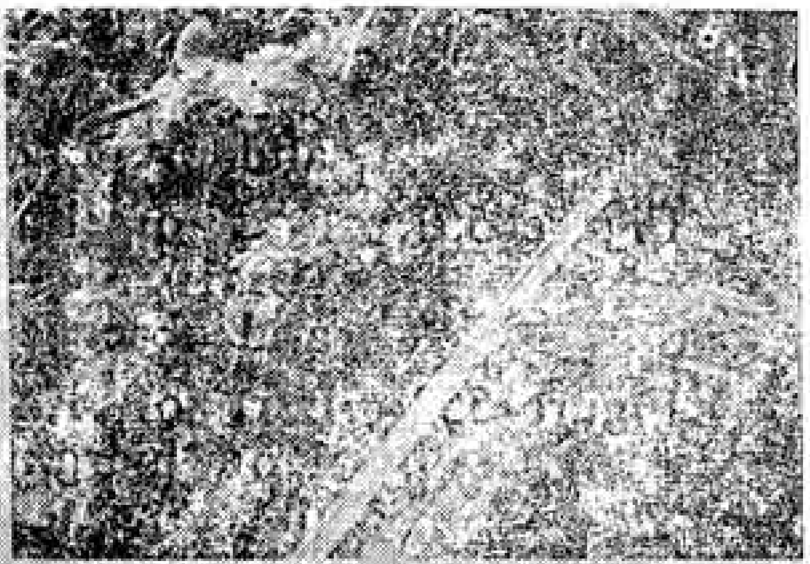
Figure 548. Plants of *Pogonatum microstomum* (R Brid) at Kodaikanal. X 3/5

Figure 549. Plants of *Pogonatum neesii* (C. M.) Mitt. at Ootacamund. X 1/4

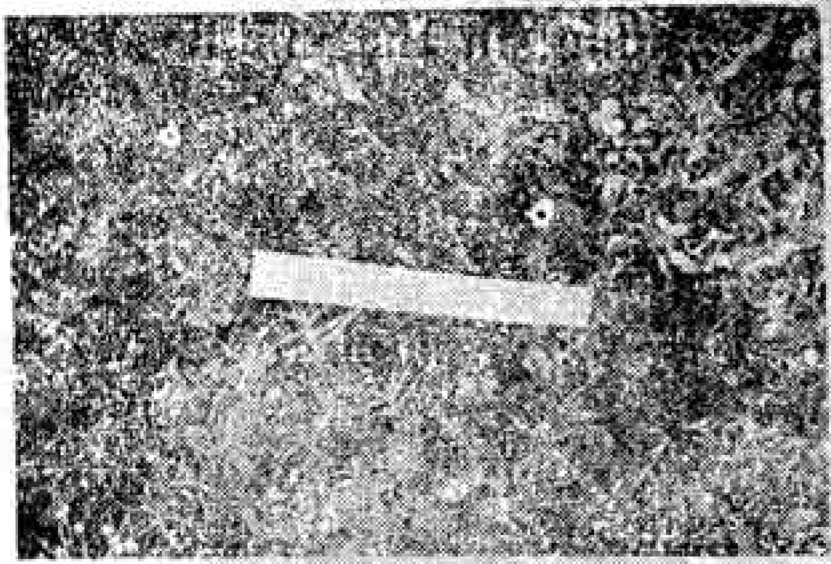
PLATE XXXVII



544



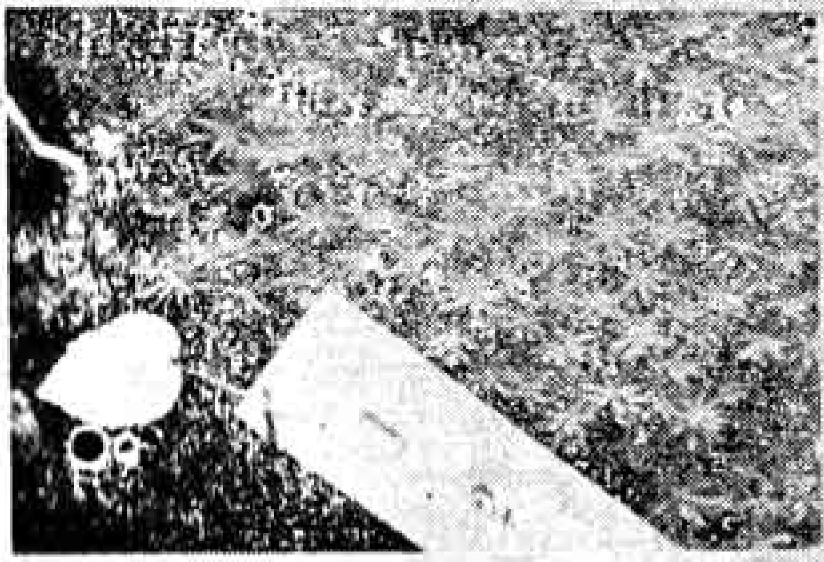
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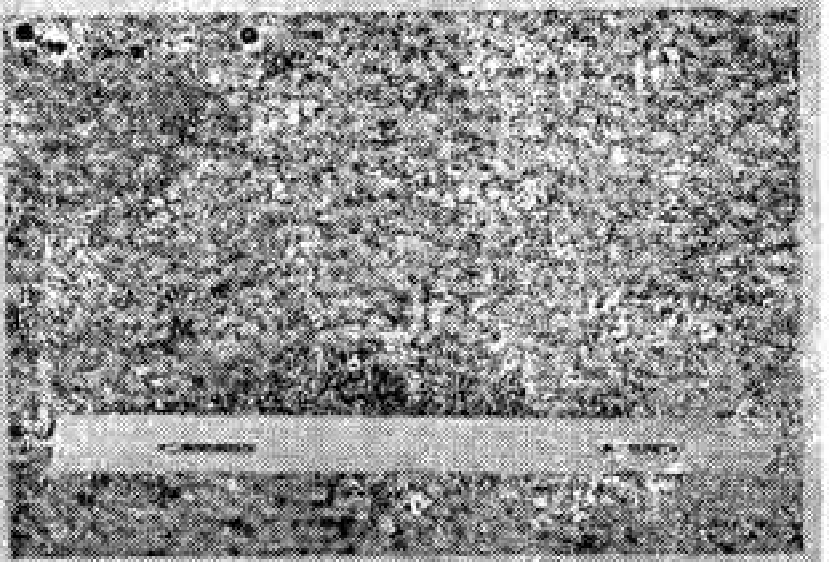
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PLATE XXXVIII

(Photomicrographs)

Figure 550. Part of leaf of *Anomobryum subniditum* Card. & Vard. Note rhomboid large cells and prominent costa. X 750

Figure 551. Part of leaf of *Sematophyllum subhumile* (C.M.) Fleish. Note narrow elongated cells and absence of mid-rib. X 490

Figure 552. Part of leaf of *Mnium coriaceum* Griff. Note margin made up of thick-walled rows of elongated cells. X 750

Figure 553. Part of leaf of *Rhodubryum giganteum* (Hook.) Par. Note serrulate margin and heavily thickened laminar cells. X 750

Figure 554. Part of leaf of *Rhegmatodon orthostegius* Mont. Note costa ending in the middle of the leaf. X 490

Figure 555. Part of leaf of *Dicranodontium fragile* (Hook.) Broth. Note broad costa and rectangular laminar cells. X 490

Figure 556. Part of leaf of *Fissidens schimidii* C. M. Note the dorsal lamella X 490

Figure 557. Part of leaf of *Ctenidium lychnites* (Mitt.) Broth. Note elongated and narrow cells of the lamina and the margin. X 490

Figure 558. Base of leaf of *Taxiphyllum taxirameum* (Mitt.) Fleisch. Note rhizoids arising from leaf base. X 490

Figure 559. Part of leaf of *Hookeria acutifolia* Hook Note large cells of lamina. X 750

Figure 560. Part of leaf of *Hypnum cupressiforme* Hedw. Note larger alar cells X 490

Figure 561. Part of leaf of *Homaliodendron flabellatum* (Dix. Sm.) Fleisch. Note different shapes of cells. X 490

Figure 562. Part of leaf of *Leucobryum neilgherrense* C. M. Note rhizoids arising from the left margin. X 490

PLATE XXXVIII

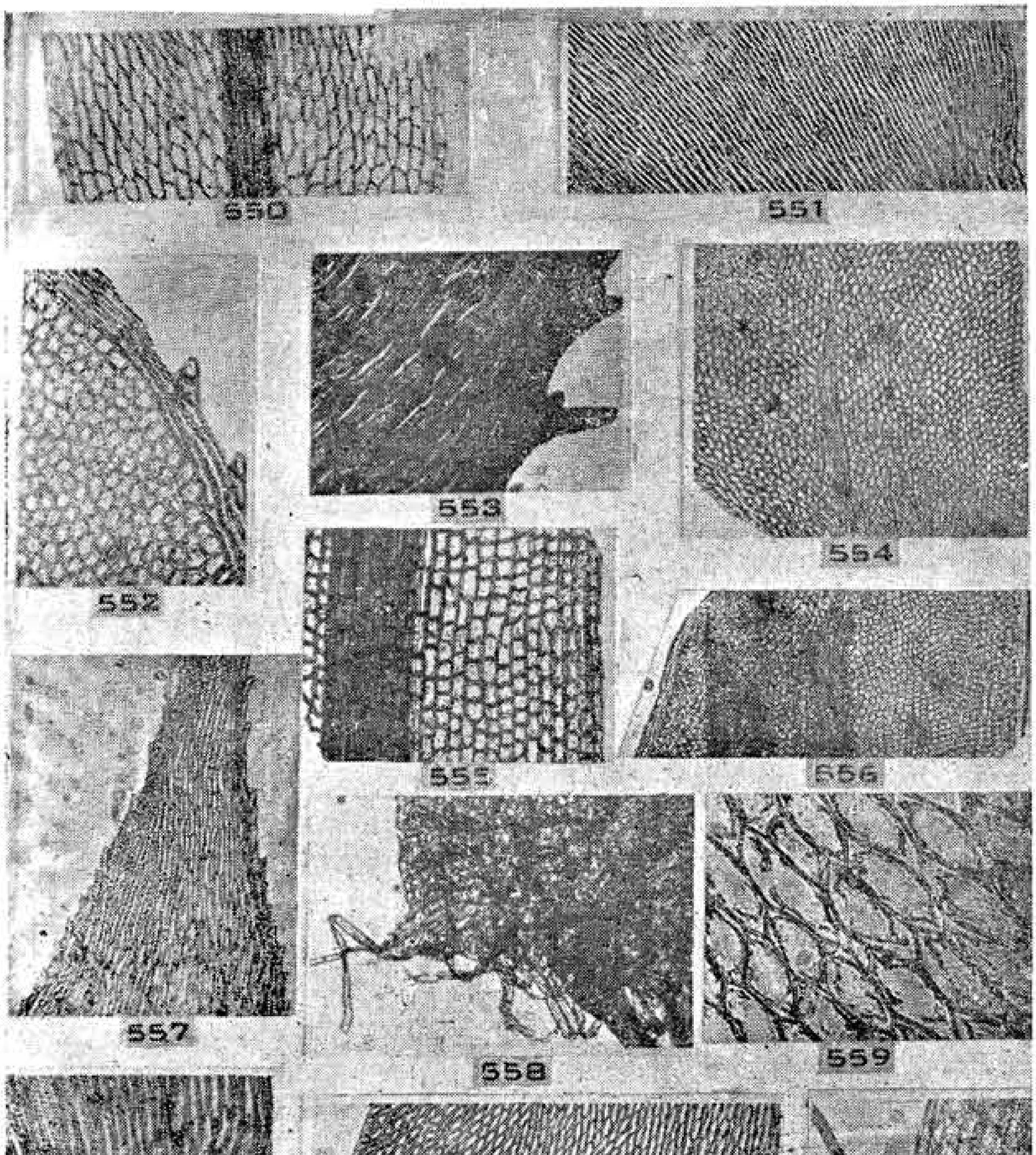


PLATE - XXXIX

(Photomicrographs)

Figure 563. Part of leaf of *Anomobryum subniditum* Card & Vard. Note excurrent costa. X 490

Figure 564. Apex of leaf of *Leucobryum neilgherrense* C. M. Note production of rhizoids from leaf apex. X 490

Figure 565. Spores of *Dicranodontium fragile* (Hook.) Broth. Note thickening of costa. X 490

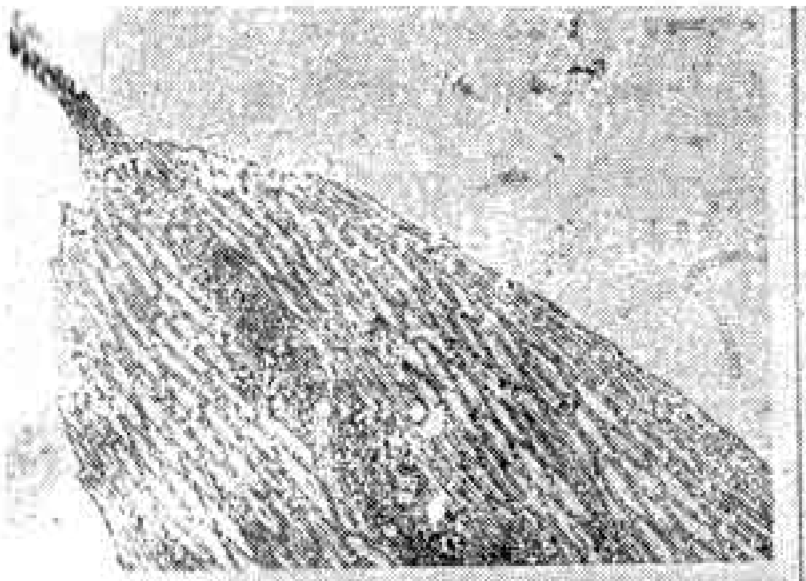
Figure 566. Part of leaf of *Funaria submarginata* Card. & Vard Note leaf base with prominent costa. X 490

Figure 567. Part of leaf of *Rhynchostegium javanicum* (Bel.) Fleisch. Note alar cells quadratic to rectangular X 490

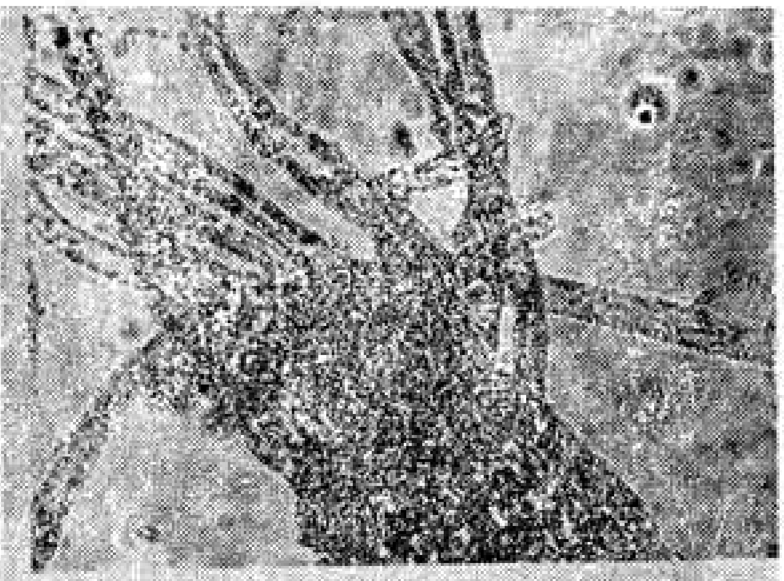
Figure 568. Peristomial teeth in *Dicranodontium fragile* (Hook.) Broth. Note Haplolepideae structure of peristome inner face. X 200

Figure 569. Part of leaf of *Barbella determessi* (Rein & Card.) Fleisch. Note absence of costa. 490

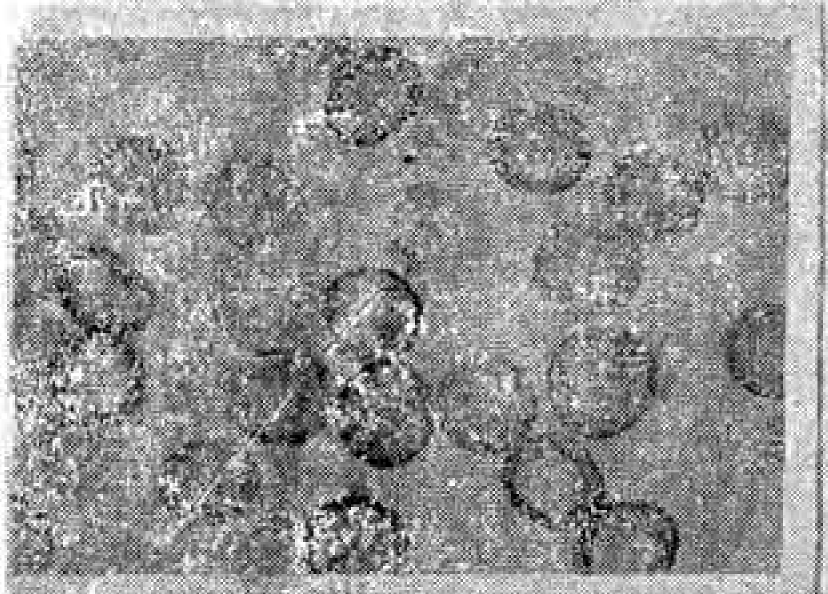
PLATE XXXIX



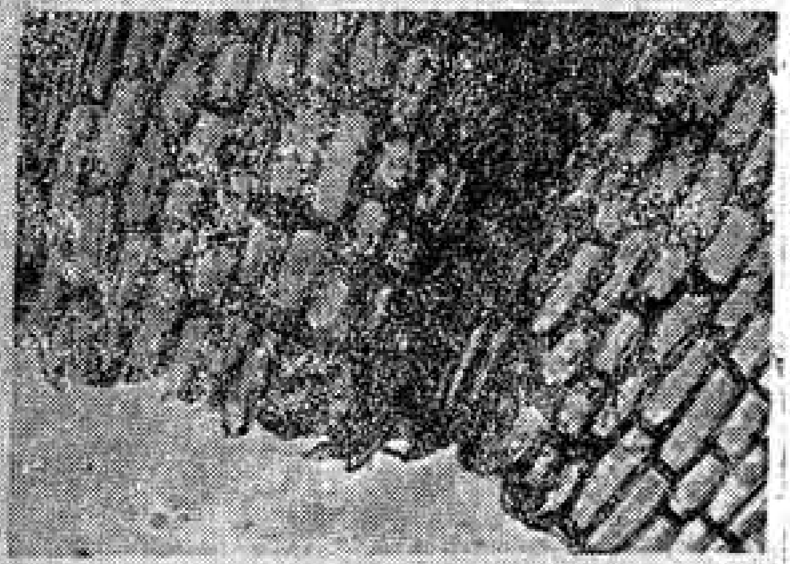
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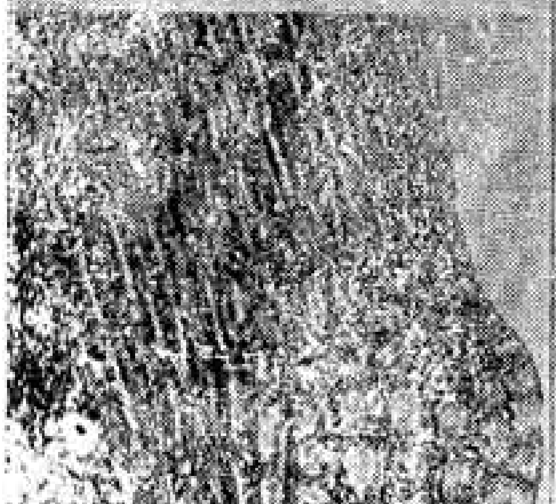
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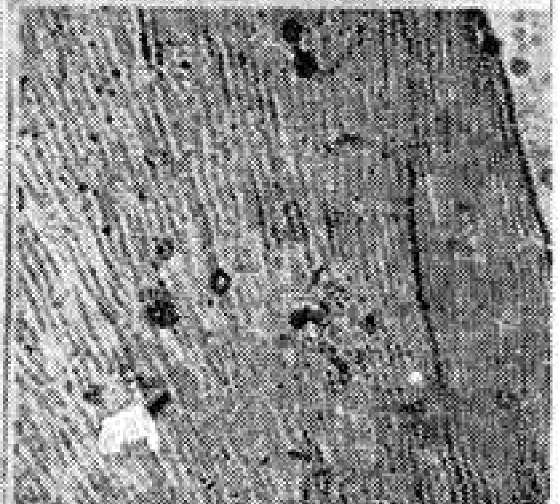
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PLATE - XL

(Photomicrographys)

Figure 570. Stomata on the apophysis of *Trematodon ceylonensis* C. M. Note elongated epidermal cells. X 750

Figure 571. Stoma on the apophysis of *Funaria hygrometrica* Hedw. Note numerous subsidiary cells of stoma. X 750

Figure 572. Transverse section of axis of *Barbella determessi* (Rein. & Card.) Fleisch. Note central small cell surrounded by a ring of cells. X 200

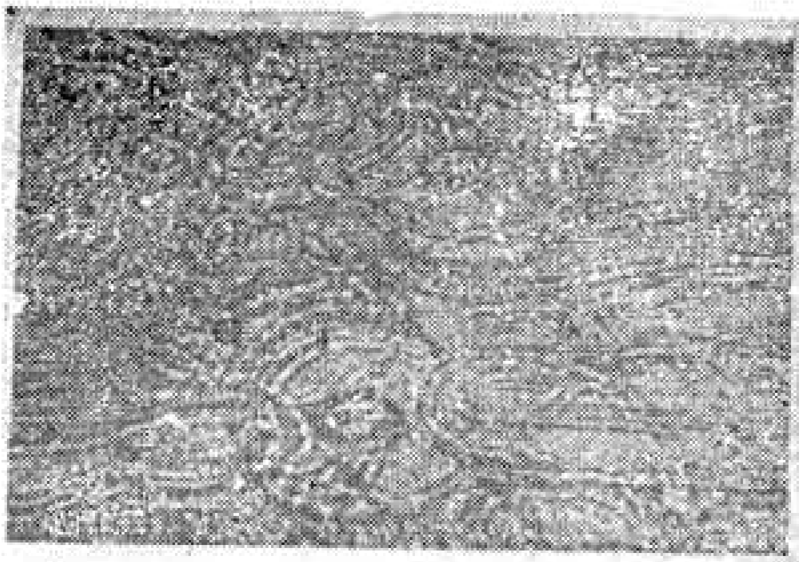
Figure 573. Stomata on the apophysis of *Funaria hygrometrica* Hedw. Note frequency of stomata. X 200

Figure 574. Transverse section of axis of *Thysanomitrium depallieri* Card. Note central axis hollowed. X 200

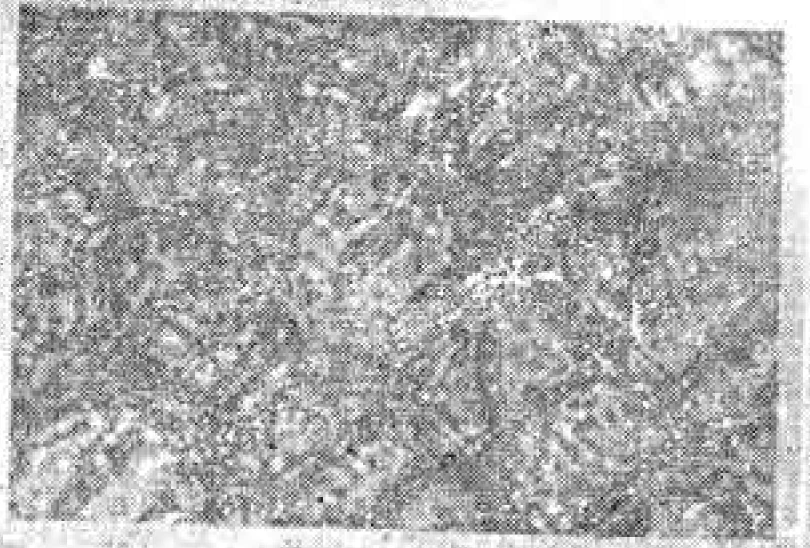
Figure 575. Part of Transverse section of axis of *Barbella determessi* (Rein. & Card Fleisch. Note organisation of cavity. X 400

Figure 576. Transverse section of axis of *Thuidium tamariscellum* (C.M.) Bryol. Note undifferentiated tissue of the axis inside the rind. X 200

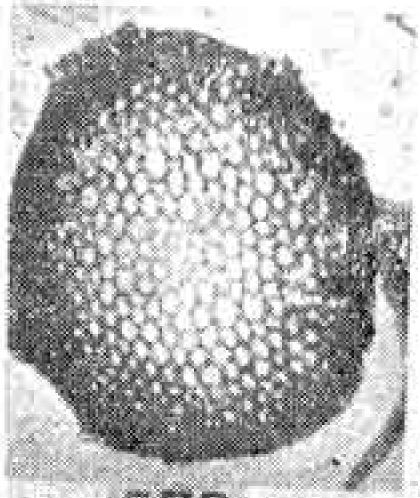
PLATE XL



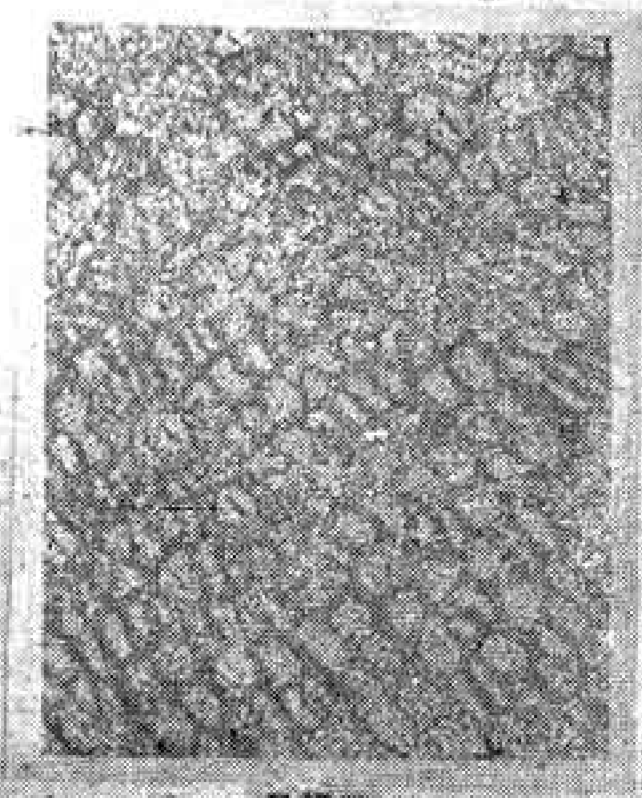
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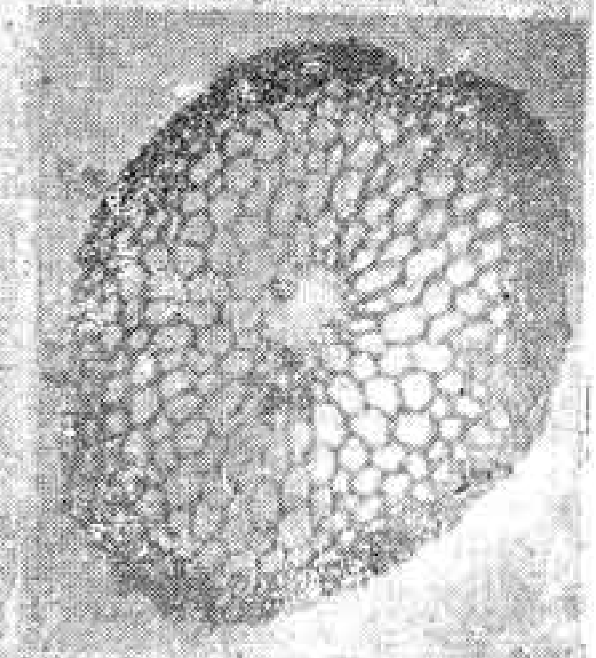
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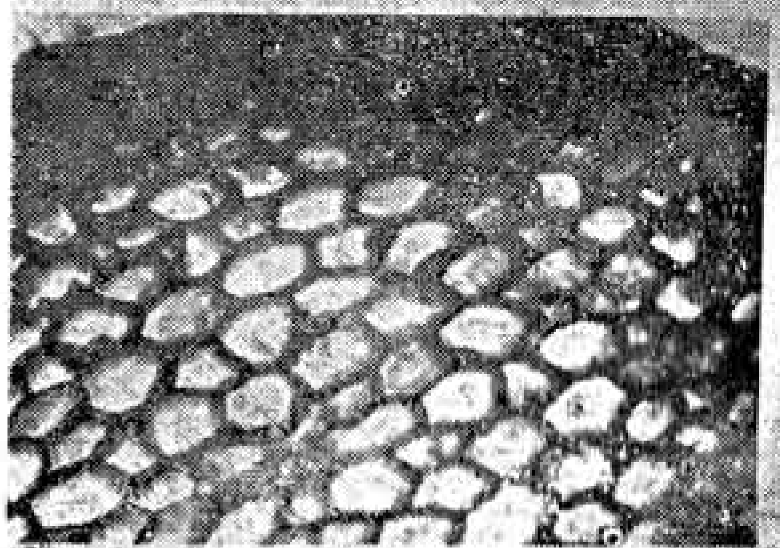
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PLATE - XLI

(Photomicrographs)

Figure 577. Longitudinal section of axis of *Homaliodendron flabellatum* (Dix. Sm.) Fleisch. Note oblique or straight cross walls. X 490

Figure 578. Part of Transverse section of *Mnium coriaceum* Griff. Note presence of pith in the centre X 490

Figure 579. Part of Transeverse section of axis of *Ctenidium lychnites* (Mitt.) Broth. Note presence of single cell with a ring of radiating and elongated cells in the centre of axis. X 490

Figure 580. Transverse section of axis of *Mnium coriaceum* Griff centre. enlarged. Note pith cells having angular thickening. X 750

Figure 581. Transverse section of axis of *Homaliodendron flabellatum* (Dix. Sm.) Fleisch. Note undifferentiated uniformly thickened cells. inside rind X 200

Figure 582. Transverse section of axis of *Hypnum cupressiforme* Hedw. centre enlarged. Note organisation of cavity. X 750

Figure 583. Transverse section of axis of *Barbella tenax* (C.M.) Broth. Note the large hollow cavity of axis. X 490

Figure 584. Transverse section of axis of *Pogonatum neesii* (C.M.) Mitt. Note the angular projection of the central stand and differentiation of cortex and also of strand. X 200

PLATE XLI

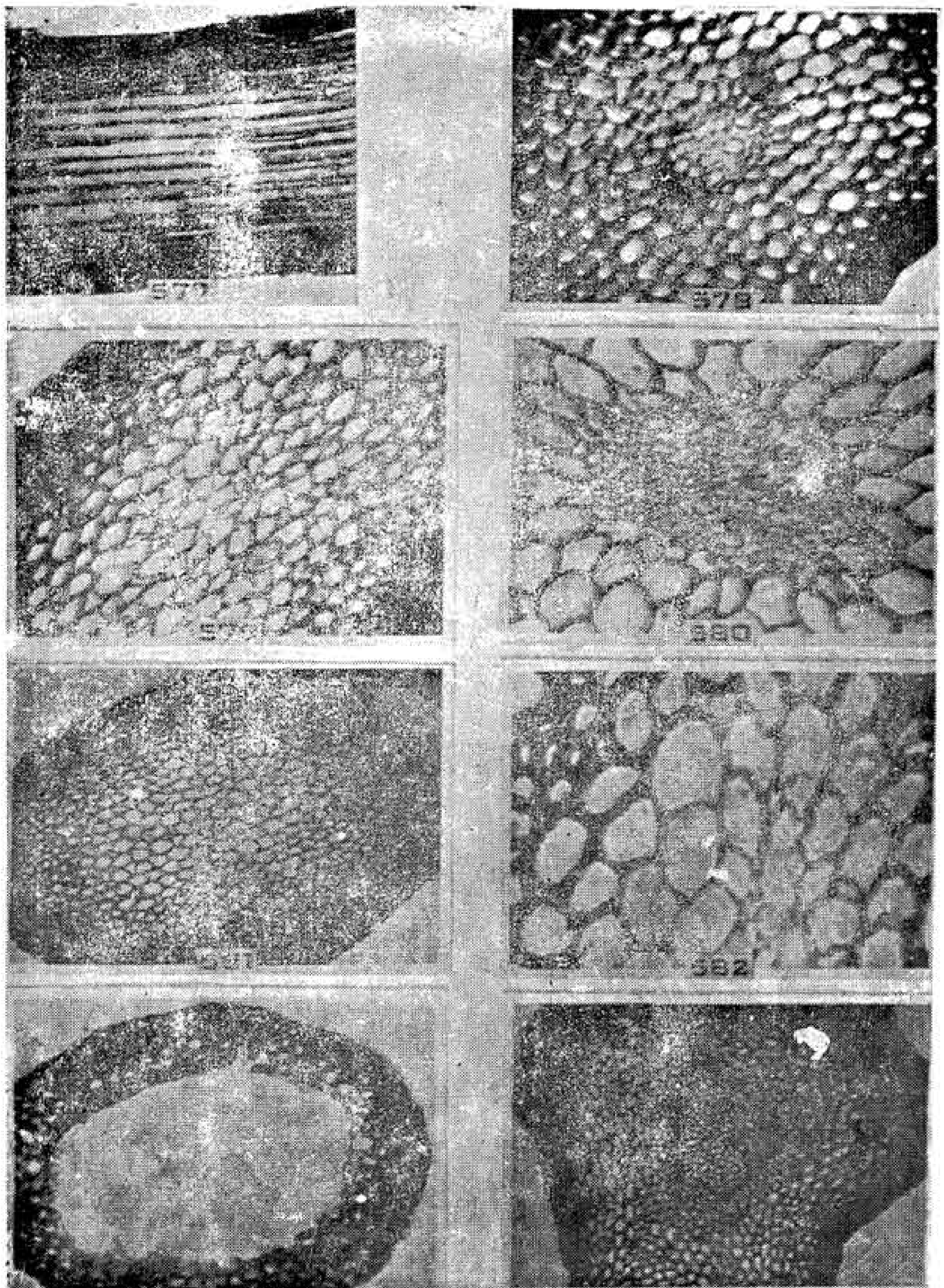


PLATE XLII

SYSTEMS OF CLASSIFICATION

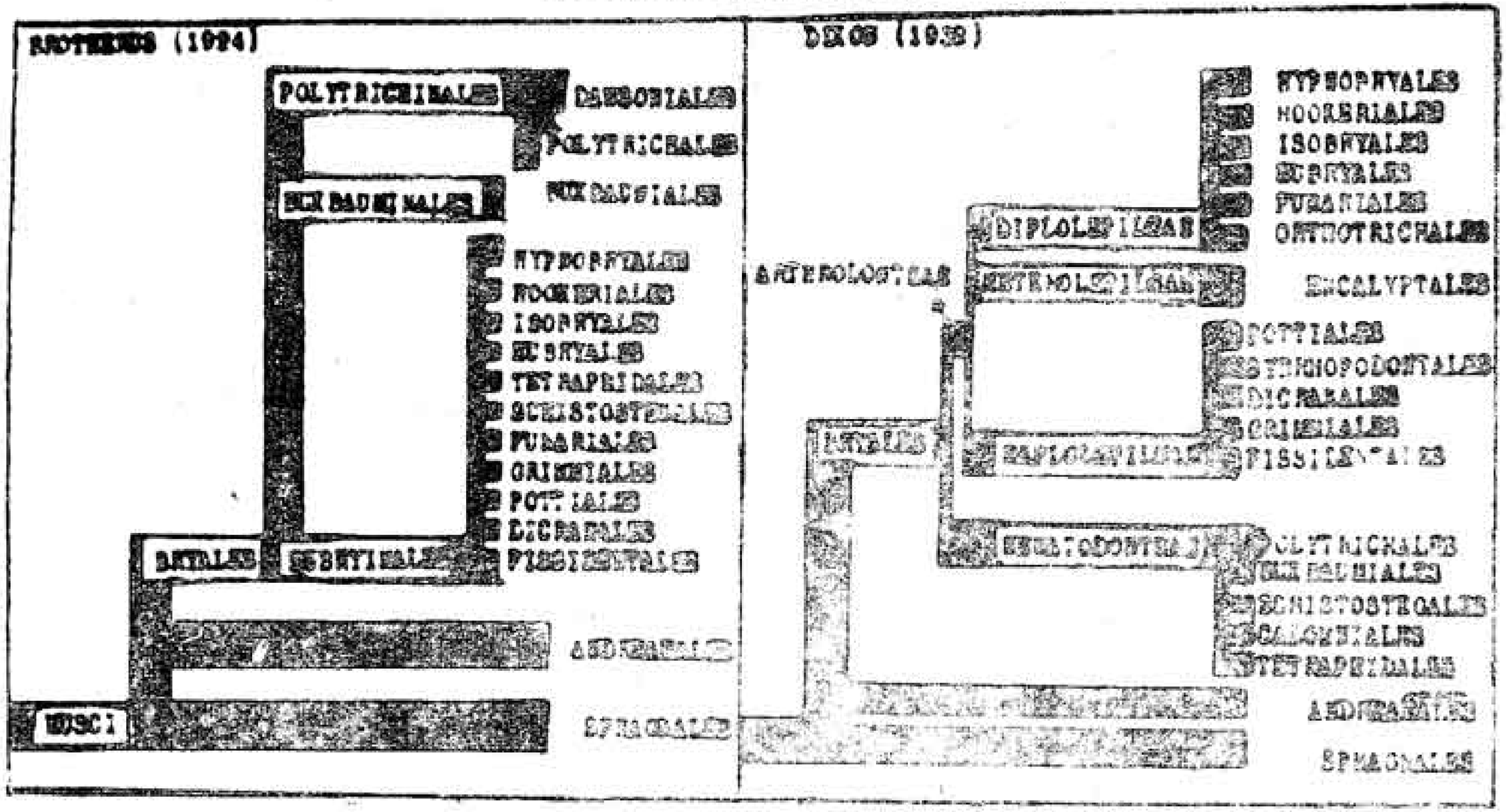


PLATE XLII (Contd.)

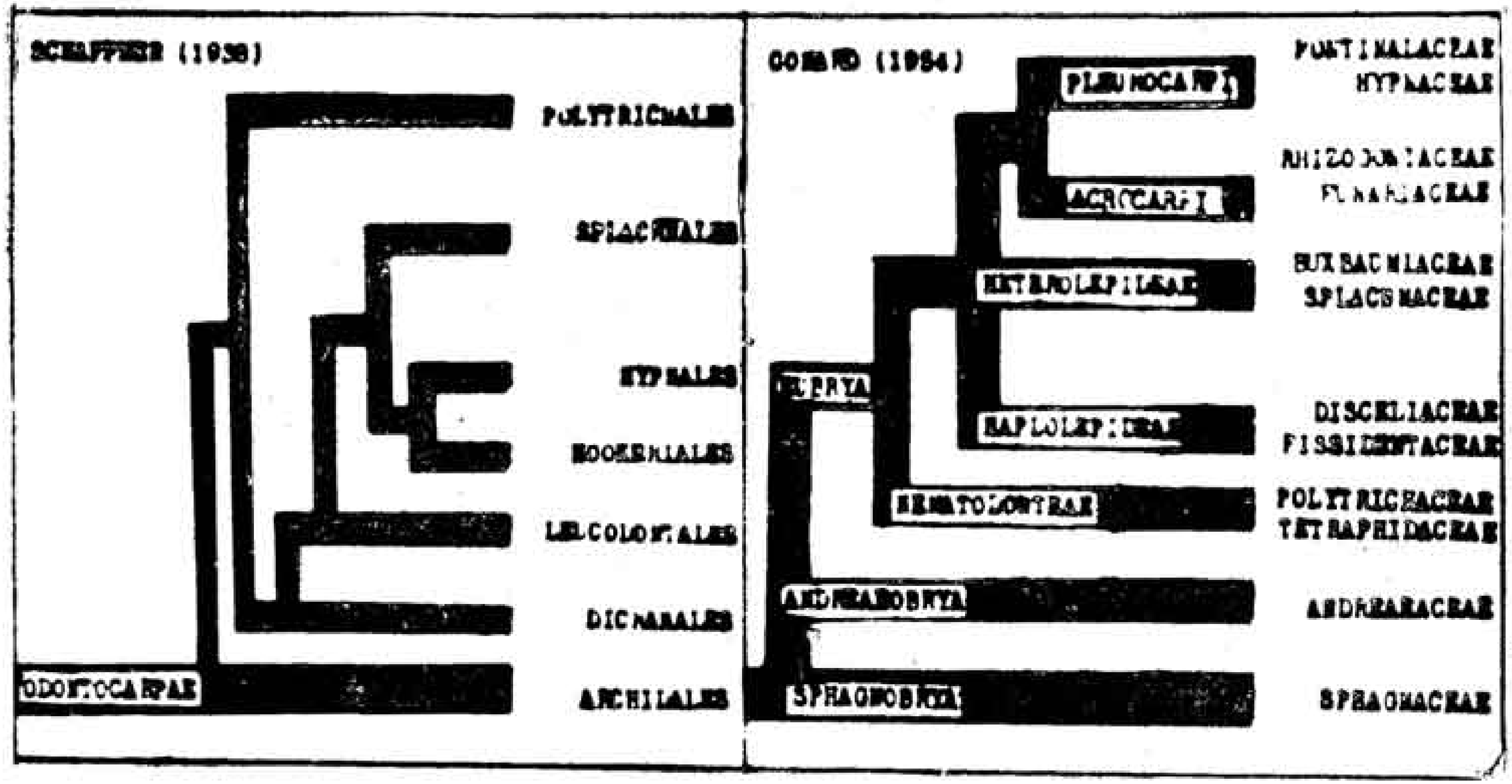


PLATE XLII (Contd.)

